A FLORISTIC ECOLOGY STUDY OF SEASONALLY WET LIMESTONE CEDAR GLADES OF TENNESSEE AND KENTUCKY

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A FLORISTIC ECOLOGY STUDY OF SEASONALLY WET LIMESTONE CEDAR GLADES OF TENNESSEE AND KENTUCKY

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Kimberly R. Norton

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To the College of Graduate Studies:

We are submitting a thesis written by Kimberly R. Norton entitled "A Floristic Ecology Study of Seasonally Wet Limestone Cedar Glades of Tennessee and Kentucky." We have examined the final copy of this thesis for form and content. We recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

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DEDICATION

I dedicate this thesis to my parents, David and Lori Norton. Everything I have ever accomplished I owe to you.

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ABSTRACT

KIMBERLY ROSE NORTON. A Floristic Ecology Study of Seasonally Wet Limestone Cedar Glades of Tennessee and Kentucky (under the direction of DR. DWAYNE ESTES.)

Limestone cedar glades of the southeastern United States are a matrix of open areas within a cedar-woodland complex. Within some of the openings exists a seasonally wet community supporting herbaceous vegetation. A floristic inventory of 10 seasonally wet sites was performed, documenting 159 species and infraspecific taxa in 131 genera and 60 families. Seventeen rare taxa, including two taxa listed as federally endangered, were documented during the study. The flora included 21 taxa not previously documented from limestone cedar glades. Cluster analysis was performed on vegetation data to compare the seasonally wet community with adjacent dry cedar glades. Cluster analysis indicated the two communities were distinct. The seasonally wet community corresponds with the Limestone Seep Glade Community described by NatureServe. A wetland assessment of this community was performed according to current wetland delineation standards. The seasonally wet community satisfied the soil, hydrology and vegetation indicators required for wetland determination. Fulfillment of the three necessary indicators suggests the Limestone Seep Glade Community is a distinct wetland community type not previously recognized. Designation of this community as a wetland could provide a new means of conserving this globally imperiled community.

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CHAPTER I

INTRODUCTION

Limestone Cedar Glades

One of the most unique ecosystems in the southeastern United States is the limestone cedar glade complex. These communities support a unique array of vascular plants including many rare and endemic species. Cedar glades occur primarily on Lebanon limestone of Ordovician age, approximately 30 m thick and horizontally bedded (Quarterman 1950, Harper 1926). The exposed limestone is covered by thin soils less than 30 cm deep, and often less than 5 cm deep (Quarterman 1950). Quarterman (1989) defines glades as "open areas of rock, gravel, and/or shallow soil that remain bare or are occupied by low-growing herbaceous plant communities." Cedar glades are often surrounded by forests of red cedar (*Juniperus virginiana*) and various hardwoods that are part of the total ecosystem, but these forests are not considered part of the true cedar glade (Quarterman 1989).

Limestone cedar glades and the surrounding cedar woods are an edaphic climax community, where the conditions remain stable for extended periods (Quarterman 1989). A cyclical, as opposed to directional, change in vegetation occurs. During heavy rainfall soil is continuously eroded as water moves across the virtually impermeable layer of limestone. The soil thus remains relatively thin (Quarterman 1989). Directional change may occur as the soil that is washed from the rock surface collects in crevices and sinkholes. As soil accumulates the propensity for soil movement across the bedrock lessens and soil builds up on the surface (Quarterman 1989). The deeper soil allows for the growth of more plants and a progression to shrub thickets and cedar woods occurs, further stabilizing the soil (Quarterman 1989). The removal of trees by drought or exogenous forces loosens the soil and can revert the system back to an open glade (Quarterman 1989).

Quarterman (1989) identifies four possibilities for the future of limestone cedar glades in the Tennessee Central Basin:

1. the indefinite persistence of herbaceous communities on thin soil;
2. progression of open areas towards cedar forests;
3. forest destruction by exogenous forces reverts forested areas to open glades; and
4. destruction of the entire system by commercial and residential development.

Definition and Use of the Term Cedar Glade

The use of the term cedar glade has been applied inconsistently over the past 150 years (Baskin and Baskin 2004). Safford (1851) was likely the first scientist to use the term when describing the vegetation in the Central Basin. He used the term to describe the "rocky places, generally flat, covered more or less, with red cedar" (Safford 1851). According to this definition, a cedar glade refers to the limestone areas supporting cedar forests. This definition was adopted by others (Killebrew and Safford 1874, Harper 1926, Bassler 1932, Wilson 1949, Hershey and Maher 1985). Gattinger (1887, 1901), the first botanist to study cedar glades, used the term to describe the cedar glade complex, including the rocky openings and the surrounding cedar forest. In her first publication, Quarterman (1947) used the term to refer to both the open areas and the surrounding cedar forest. In later articles, Quarterman referred to the open areas by terms such as "limestone cedar glades," "gravelly/grassy true glades" (1989), and "limestone glades" (Quarterman et al. 1993). According to this usage, the cedar forests surrounding the open areas are not considered glades, but are considered part of the cedar glade complex. Thus Quarterman suggested that the term limestone cedar glades be used to refer specifically to the open areas with exposed rock (Quarterman 1989). Quarterman also distinguishes between cedar glades and the superficially similar cedar barrens or xeric limestone prairies, which also occur in the open areas within the cedar glade/forest matrix. Xeric limestone prairies are dominated by perennial grasses, while cedar glades are dominated by annual grasses (Quarterman 1989). Cedar glades typically have thinner soil (less than 10 cm) and more exposed bedrock than xeric limestone prairies. Additionally, cedar glades are a natural community, whereas xeric limestone prairies were the result of land clearing for agricultural purposes (Lawless et al. 2004). This use of the term cedar glade has now been adopted by most botanists including Ware (2002), Baskin and Baskin (1973, 1985, 1986, 1989, 1999, 2003), Bridges and Orzell (1986), Delcourt et al. (1986), Eichmeir (1986) and Somers (1986). In this paper, the terms limestone cedar glade and cedar glade will be used interchangeably according to the Quarterman (1989) definition referring specifically to the open, level areas with less than 50 percent cover of dominated by annual grasses and soils typically less than 10 cm in depth.

Distribution

Cedar glades occur in the southeastern United States, primarily in the Interior Low Plateaus Physiographic Province of southern Kentucky, central Tennessee, and northern Alabama (Fig. 1.1) (Baskin and Baskin 1986). The largest concentration of cedar glades is in the Central Basin of Tennessee (Baskin et al. 1995, Bridges and Orzell

1986). Within the Basin surface rock is primarily Ordovician limestone with an average elevation of approximately 180 meters above sea level (Harper 1926). Cedar glades often, though not exclusively, occur on the lowest and oldest exposed rock in the Basin, and are separated from one another by uplands and rolling hills, making them disjunct within the region (Quarterman 1950). Exposed Lebanon limestone, which prior to development would have supported cedar glades and cedar forests, comprises approximately 780 square kilometers of the Central Basin, or 5 to 6 percent of the total area (Harper 1926). Noss et al. (1995) estimates that over half of this area has been lost to development and agriculture.

Limestone cedar glades are disjunct from the Central Basin to the north in the Outer Blue Grass and Kentucky Karst Plain (Baskin and Baskin 2003), and to the south in the Highland Rim (Interior Low Plateaus Physiographic Province) and the western escarpment of the Cumberland Plateau (Appalachian Plateaus Province) in Alabama (Baskin et al. 1995). Most of Alabama's cedar glades occur in the Moulton Valley (Highland Rim) (Baskin et al. 1995). These were not previously considered equivalent to the glades of the Tennessee Central Basin (Harper 1926, Baskin and Baskin 1996), but a comparative floristic study by Baskin et al. (1995) showed that the Moulton Valley glades are "true" cedar glades.

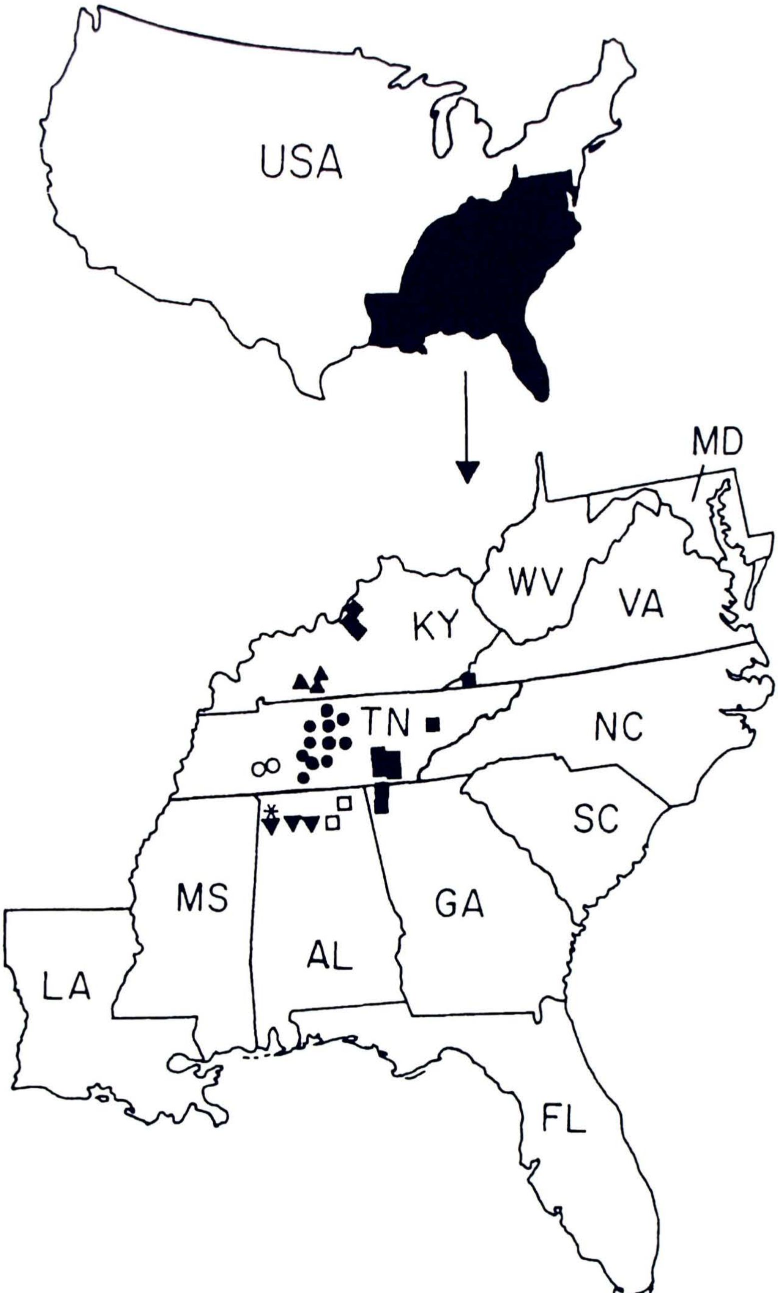


Figure 1.1 - Distribution map of cedar glades in southeastern United States. Each symbol represents all cedar glades in a county. (♦) Outer Bluegrass, (▲) Kentucky Karst Plain, (●) Central Basin, (○) Western Valley, (★) Tennessee Valley and Little Mountain (combined), (▼) Moulton Valley, (□) Sequatchie Valley, (■) Ridge and Valley. Following Fenneman's (1938) boundaries of physiographic provinces, the first seven regions are in the Interior Low Plateau, the eighth (Sequatchie Valley) is in the Appalachian Plateaus, and the ninth is the Ridge and Valley (used with permission from Baskin and Baskin 2003).

True cedar glades also occur in the Ridge and Valley physiographic province of east Tennessee and northwest Georgia. Glades superficially similar to the cedar glades of these areas also occur in the Ridge and Valley Physiographic Province in Alabama, Virginia, and West Virginia. In addition similar systems also occur in the interior lowlands of southern Ohio, southern Indiana, and southern Illinois; the Ozark region of Missouri, Arkansas and southeast Oklahoma; and the Edwards Plateau of Texas (Baskin and Baskin 1986). Though these areas superficially appear similar to true cedar glades, they differ floristically and the term cedar glade as used in this paper is not inclusive of these areas.

Flora

Limestone cedar glades occurring in central Tennessee, southern Kentucky and northern Alabama are distinguished from similar glades in other regions by their unique and characteristic flora (Quarterman 1989). Baskin and Baskin (2003) compiled a list of the vascular flora of limestone cedar glades identifying 448 native plant species and 96 non-native species. Asteraceae and Poaceae comprise the largest families and *Carex, Hypericum,* and *Panicum* comprise the largest genera. Dominant vegetation includes "C_4 summer annual grasses, C3 winter annuals, summer annuals, perennial herbaceous dicots, mosses [primarily *Pleurochaete squarrosa], Nostoc commune*...and crustose, foliose, and fruticose lichens" (Baskin and Baskin 2003).

Bridges and Orzell (1986) analyzed 270 native cedar glade taxa and found that approximately 50 percent could be considered characteristic of glades and prairies, with 19 percent being characteristic of calcareous glades, prairies, and rocky forests. Among the 448 native plants that inhabit cedar glades there are as many as 29 endemic or near endemic taxa (Baskin and Baskin 1986, 2003; Estes unpublished data). Baskin and Baskin (1986) define a cedar glade endemic as a plant taxon that is, or historically was, restricted or almost restricted to cedar glades and glade-like areas. Among the cedar glade endemics (Table 1.1), 14 are considered rare and are of conservation concern, including three federally endangered taxa, *Dalea foliosa, Echinacea tennesseensis, Astragalus bibullatus* Barneby & Bridges and *Paysonia lyrata* (Rollins) O'Kane & Al-Shehbaz (U.S. Fish and Wildlife Service 2009, Baskin and Baskin 1989).

In addition to endemics, taxa disjunct from other ecoregions or physiographic provinces add to the unique nature of the cedar glade flora. *Ammoselinum popei* Torr. & Gray, *Evolvulus nuttallianus* Roem & Schult., *Oenothera macrocarpa, Onosmodium molle* Michx. var. *subsetosum* (Mackenzie& Bush) Cronquist and *Solidago gattingeri* Chapm. are disjunct from the Interior Highlands or Great Plains (Baskin and Baskin 2003, Bridges and Orzell 1986). *Astragalus tennesseensis* Gray ex. Chapm., *Dalea foliosa* and *Gratiola quartermaniae* are cedar glade taxa disjunct to the Midwest north of the glacial boundary (Baskin and Baskin 1989). *Hypericum dolabriforme, Viola egglestonii* Brainerd and *Onosmodium molle* Michx. var. *molle* are endemic to the Southeast as well as either southern Indiana or southern Illinois (Baskin and Baskin 1989). *Juncus filipendulus* has a bicentric distribution pattern, with half of its range restricted to the Edwards Plateau of Texas and the other half to the glades of the Interior Low Plateau. The high number of endemic, disjunct, and characteristic taxa represented serves to make cedar glades the most botanically unique ecosystem in Tennessee (Somers 1986).

Table 1.1 – List of taxa endemic to limestone cedar glades, including the state and federal conservation status for each species. (TN=Tennessee, T=Threatened, E=Endangered, SC=Special Concern, *=Possibly Extirpated) (Crabtree 2008, KSNPC 2006, Baskin and Baskin 2003).

Cedar Glade Endemic	Conservation Status	
	State	Federal
Allium sp. nov.		
Astragalus bibullatus	TN-E	E
Astragalus tennesseensis Gray	TN-SC	
Dalea foliosa	TN-E, KY-E	E
Dalea gattingeri		
Delphinium alabamicum		
Delphinium carolinianum ssp. *calciphilum*	KY-T	
Echinacea tennesseensis	TN-E, KY-E	E
Eleocharis bifida		
Hypericum dolabriforme		
Leavenworthia alabamica		
Leavenworthia crassa		
Leavenworthia exigua var. *exigua*	TN-SC	
Leavenworthia exigua var. *laciniata*	KY-T	
Leavenworthia exigua var. *lutea*	TN-E *	
Leavenworthia stylosa		
Leavenworthia torulosa	KY-T	
Leavenworthia uniflora		
Lobelia appendiculata var. *gattingeri*	KY-E	
Oxalis priceae ssp. *priceae*		
Paysonia lyrata		E
Pediomelum subacaule		
Penstemon tenuiflorus		
Phacelia dubia var. *interior*		
Solidago gattingeri	TN-E	
Symphyotrichum priceae		
Talinum calcaricum	TN-SC	
Trifolium calcaricum	TN-E	
Viola egglestonii		

Environmental Pressures

Cedar glades are an extreme environment year round with thin soil, saturated in the winter and early spring, and drought-like conditions during the summer. Over half the annual precipitation in the Central Basin occurs in winter and early spring with an average of 11.05 cm per month between December and May, with a high of 12.85 cm in May (Fig. 1.2) (NOAA 2010). This results in saturated soil or standing water throughout the winter and spring due to impenetrable horizontally bedded limestone bedrock near the surface. A reduction in precipitation begins in spring and continues through the summer with an average of 9.32 cm per month between June and November, reaching a low of 7.29 cm in October (Quarterman 1950). Decreased rainfall combined with increased summer temperatures and evaporation loss result in soils drying out during the summer (Quarterman 1989). Thus the same area experiences both moisture extremes during the course of the year. The number of plant species capable of inhabiting cedar glade areas is limited by this hydrologic flux (Quarterman 1950).

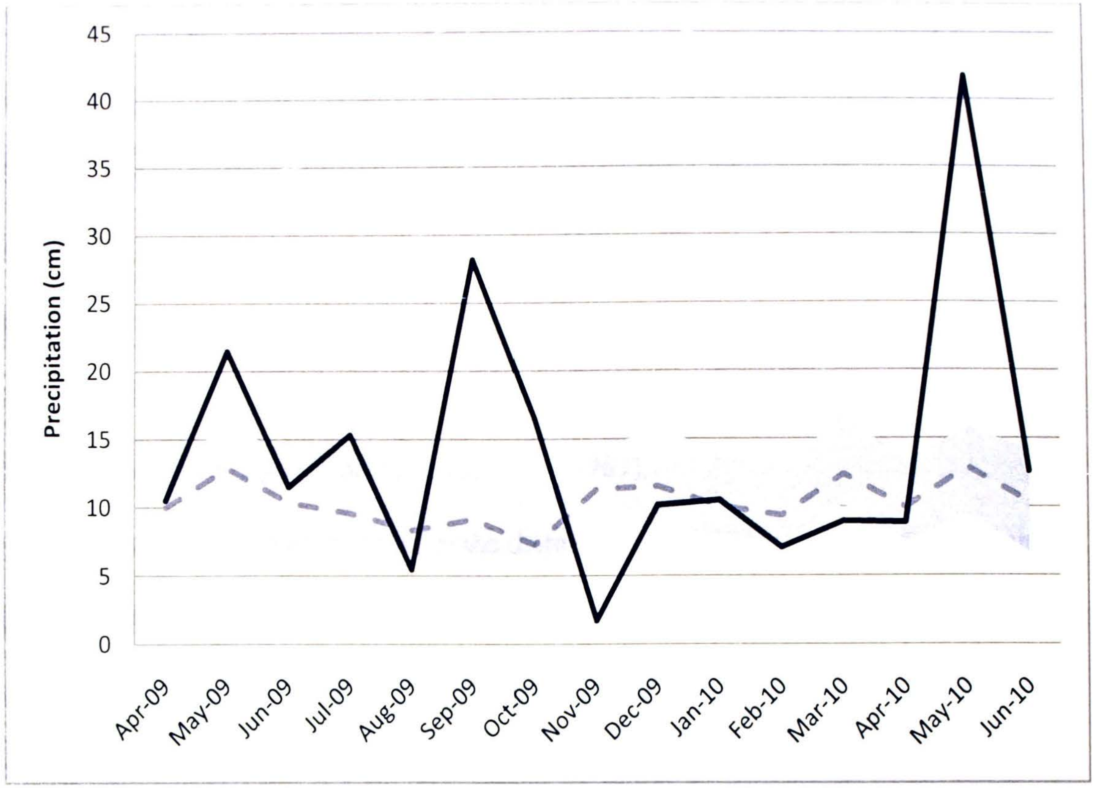


Figure 1.2 - Precipitation data for Nashville, TN during the study time frame. Dotted line indicates average rainfall with the gray shading indicating the normal range of precipitation. The black line indicates the actual precipitation for the given month. Record rainfall in May 2010 resulted in severe flooding in the area (NOAA 2010).

There are several strategies used by plants inhabiting extreme environments. The first is adapting to local conditions. This ecological specificity could serve to limit the ranges of species utilizing this method to cedar glade and glade-like areas. The high number of endemics in the Central Basin of Tennessee may be due to this specialization to local conditions, or ecological endemism (Estill and Cruzan 2001).

The glade endemic *Leavenworthia uniflora* is adapted for growth under anaerobic conditions such as those occurring in saturated soil typical of early spring. Baskin and Baskin (1989) found that ethanol accumulation in the roots did not occur during flooding.

Species not adapted for saturated conditions would typically accumulate ethanol in the roots, often proving detrimental to the plant during flooding. The average growth rate (mg g-1 day-1) in flooded soil was about 80 percent that in non-flooded soil, allowing *L. uniflora* to survive and thrive early spring conditions. The glade endemic *Phemeranthus calcaricus* is a poor competitor with other plants, but is highly resistant to drought with a succulent shoot and thick leaf cuticle, allowing it to survive in the drought-like summer conditions of cedar glades (Baskin and Baskin 1989).

Many species have adapted to the distinct wet and dry seasons by completing their life cycle before hydrologic conditions change. During spring saturation *Leavenworthia* spp., *Gratiola quartermaniae, Nothoscordum bivalve, Schoenolirion croceum, Isoetes butleri, Oxalis violaceae* L., *Houstonia purpurea* var. *calycosa, Ophioglossum engelmannii, Minuartia patula* and others dominate the flora (Quarterman 1950). These go dormant by early summer and give way to another group of vegetation that was dormant during the wet period. *Aristida* sp., *Manfreda virginica, Evolvulus nuttallianus, Grindelia lanceolata, Heliotropium tenellum, Isanthus brachiatus* and *Sporobolus vaginiflorus* dominate the drier summer (Quarterman 1950). The time of dormancy allows glade plants to survive both the winter/spring saturation and drought of summer/fall (Quarterman 1950).

One possible adaptation to dry summer conditions is the development of C_4 and CAM photosynthetic pathways. All three photosynthetic pathways are represented in the cedar glades, with 88.9 percent of species utilizing the C_3 pathway, 7.8 percent the C_4 pathway and 1.2 percent as obligate or facultative CAM species (Eickmeir 1986). This suggests that though the glade environment may be extreme, it is not necessary to evolve

C_4 and CAM photosynthetic pathways for survival. However, this does not mean these adaptations are not beneficial and highly utilized by glade species. Three of the most dominant grass genera within the glades, *Andropogon* (including *Schizachyrium*), *Aristida and Sporobolus* utilize the C_4 photosynthetic pathway. The result is that the biomass contribution of C_4 plants in cedar glades is considerably greater, particularly during summer, than the number of taxa alone suggests (Eickmeir 1986).

Despite the dominance of C_4 and CAM pathways during the summer, all 23 cedar glade endemics reviewed by Baskin and Baskin (1989), were C_3 plants. All 23 species also grew well in non-glade soil. In fact Baskin and Baskin found nothing about their autecology that explained their restriction to cedar glades, except for their poor competitive ability with other taxa. The specific adaptations that allow the endemics to survive in the extreme conditions present in the glades may also limit their competitive ability, restricting them to the low competition environment of the glades.

Though many glade taxa have evolved specific adaptations enabling their survival, as is seen with the 23 endemic species, not all have adopted this strategy for survival. Most taxa associated with cedar glades grow in a variety of habitats and are widely distributed geographically (Baskin and Baskin 2003). Like most of the endemic species, many glade inhabitants are poor competitors against mesic species that occur in the more favorable surrounding environments (Quarterman 1950). Those species capable of tolerating the harsh conditions thus grow uninhibited by more competitive species (Quarterman 1950). Weedy species are also found in cedar glades, though the extreme conditions often limit their abundance. Thus cedar glade vegetation is comprised of plants that have specifically evolved to the conditions present, plants that are poor competitors but can tolerate the difficult environment, and weedy species that are kept in check by the same harsh conditions that allow the other taxa to survive.

Plant Communities

Several classification systems have been applied to cedar glade vegetation. Most systems divide communities into two classes based on vegetation and substrate. Xeric communities, also referred to as gravel glades or Zone 1, generally have soil less than 5 cm deep. Subxeric communities, also referred to as grass glades or Zone 2, generally have soils from 5 to 20 cm deep (Somers 1986, Quarterman 1989). These classes can be subdivided into seven community types based on dominant vegetation (Table 1.2) (Somers 1986). The Xeric class is divided into communities 1 through 4, while the Subxeric class is divided into communities 5 through 7. Soil depth is shallowest in community 1, the *Panicum capillare* community, with an average soil depth of 3.5 ± 1.7 cm. Soil depth deepens in each successive community, reaching a maximum in community 7, the *Panicum flexile-Pleurochaete squarrosa-Sporobolus vaginiflorus* community, at 9.1 ± 4.1 cm (Somers 1986). Not all community types and characteristic species will occur in all glades, as the glades are geographically disjunct and vary with respect to structure (Baskin and Baskin 1996).

Table 1.2 – Vegetation communities occurring on limestone cedar glades. Communities are classified according to the dominant vegetation and depth of soil (Somers 1986).

Community Type	Frequency	Mean Soil Depth ± S.D.	Dominant Vegetation
1. *Panicum capillare* Community	4%	3.5 ± 1.7 cm	Annual grasses , forbs; glade-moss
2. Foliose Lichen Community	6%	3.6 ± 2.2 cm	Foliose lichens; *Dalea gattingeri, Sporobolus vaginiflorus*
3. *Nostoc commune-Sporobolus vaginiflorus* Community	24%	4.1 ± 3.4 cm	*Nostoc commune, Sporobolus vaginiflorus*
4. *Dalea gattingeri* Community	26%	4.5 ± 1.8 cm	*Dalea gattingeri, Sporobolus vaginiflorus, Isanthus brachiatus*
5. *Sporobolus vaginiflorus Community*	22%	5.9 ± 2.6 cm	*Sporobolus vaginiflorus, Dalea gattingeri*
6. *Pleurochaete squarrosa* Community	8%	7.7 ±3.4 cm	*Pleurochaete squarrosa, Panicum flexile, Ruellia humilis*
7. *Panicum flexile-Pleurochaete squarrosa-Sporobolus vaginiflorus* Community	10%	9.1 ± 4.1 cm	*Panicum flexile, Pleurochaete squarrosa, Sporobolus vaginiflorus, Schizachyrium scoparium, Carex crawei, Ruellia humilis, Heliotropium tenellum, Cladonia* spp.

The community classification systems of Quarterman and others thoroughly describe the dry, rocky portions of glades. The seasonal saturation present in the glades however is not uniform throughout the entire community. Whereas a significant portion of a given glade may be characterized by rocky upland conditions and appear almost desert-like, other areas within the same glade system may exhibit characteristics that resemble wetlands. Though very useful, none of the classification systems previously mentioned discusses areas with saturated conditions. A relatively new community classification system, NatureServe (2009), identifies two communities within limestone cedar glades that are characterized by saturated soil and herbaceous vegetation: the Limestone Seep Glade/Kentucky Glade Seep and Limestone Glade Streamside Meadow.

The Limestone Seep Glade/Kentucky Glade Seep community type (GS), also referred to as the "*Eleocharis (bifida, compressa) – Nothoscordum bivalve* Saturated Herbaceous Alliance," is a zonal component of limestone cedar glades. This community occurs in the Interior Low Plateau physiographic province in the Central Basin of Tennessee and limestone cedar glades of the Highland Rim of south-central Kentucky, as well as in the Moulton Valley of Alabama. This community occurs where "seasonal seepage of unconfined aquifers emerges during the winter and spring, resulting in lateral seepage or flow of mineral-rich, circumneutral waters" (NatureServe 2009). Tennessee examples occur on Ordovician limestone, while Kentucky and Alabama examples occur on Mississippian limestone. Tennessee examples, referred to as the Limestone Seep Glade community, are dominated by some combination of *Eleocharis bifida, Schoenolirion croceum, Carex crawei,* and an undescribed species of *Allium* (Norton and Estes, in prep.) identified by past workers as *A. cernuum. Nothoscordum bivalve, Isoetes butleri,* and *Hypoxis hirsuta* are other characteristic species. Kentucky examples, referred to as the Kentucky Glade Seep community, contain *Eleocharis bifida, Nothoscordum bivalve, Isoetes butleri,* and *Hypoxis hirsuta* but lack *Schoenolirion croceum* and *Allium* sp. nov., two of the characteristic dominants of the Tennessee and Alabama sites. Little detailed information is available on the floristics of the Kentucky examples and how they compare to examples in Tennessee. This lack of information on the Kentucky sites is the reason for having two community classifications, though additional work may lead to the consolidation of these community types.

The Limestone Seep Glade has a global rank of G2, or globally imperiled, while the Kentucky Glade Seep is not ranked. A rank of G2 indicates a community is "at high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors (NatureServe 2009)." Although unranked, the Kentucky Glade Seep is certainly at risk of extinction with few intact cedar glade systems remaining in Kentucky.

The Limestone Glade Streamside Meadow community (SM), also known as the *Dalea foliosa – Mecardonia acuminata* Saturated Herbaceous Alliance, is a zonal component of limestone cedar glades. Occurring on glades overlaying limestone in the Central Basin of Tennessee, this seasonally saturated community occupies the thin soil bordering ephemeral streams running through open glades. Dominant vegetation includes some combination of *Mecardonia acuminata, Dalea foliosa, Mitreola petiolata, Rudbeckia triloba, Ludwigia microcarpa* Michx. and various nonvascular plants. NatureServe (2009) does not report this community from outside Tennessee. This community has a global rank of G2, or globally imperiled, due to its restricted range, vulnerability to threats at different scales, and highly specific habitat preference (NatureServe 2009).

Seasonally Wet Cedar Glades

The cedar glade system as a whole is often perceived as a dry, upland habitat by both local residents and the scientific community. This perception is supported by the rocky conditions, dry, cracked summer soil, grass-dominated summer glade flora, presence of cactus, and cedar dominated forests. This perception has resulted in the neglect of potential seasonal wetland communities within the cedar glade system. Of the 541 cedar glade taxa documented by Baskin and Baskin (2003), about 20 percent of those with designated wetland codes are obligate or facultative wet. This 20 percent appear to comprise the dominant vegetation in the Limestone Seep Glade/Kentucky Glade Seep, and Limestone Glade Streamside Meadow communities. Additionally, about half of the glade taxa, including many endemic species, have no designated wetland code and may be unrecognized hydrophytes. The community classification systems of Quarterman and others thoroughly describe the dry portions of glades; however, the wet portions have not been adequately characterized. NatureServe (2009) addresses two community types characterized by seasonal saturation, but how these communities relate to the current classification system has not been addressed.

Objectives

The objectives of this study are:

1. Conduct a floristic inventory of the seasonally wet cedar glade communities.
2. Characterize the vegetation and community structure of the seasonally wet areas and determine if these areas represent a distinct community type.
3. If so, determine if these communities are synonymous with the GS and SM communities described by NatureServe (2009).
4. Compare the flora and vegetation from study sites in Kentucky and Tennessee.
5. Determine if the seasonally wet communities meet the vegetation requirement to be classified as wetlands as presently defined by the U.S. Army Corps of Engineers Wetland Delineation Manual and appropriate regional supplements (1987, USACE 2008).

CHAPTER 2

MATERIALS AND METHODS

Ten limestone cedar glades, each suspected of containing limestone glade seep or limestone glade streamside meadow communities were selected for study. The study area included seven sites in central Tennessee, and three sites in south-central Kentucky. Each site, as defined here, consisted of an open glade with at least one seasonally wet section. Most sites included the entire open region with the dry glade woods constituting the site boundary. In cases of large open glades, an artificial boundary was selected and marked with GPS coordinates to include all wet portions of the glade and at least an equal amount of dry glade. Glades with evidence of extreme and continuing disturbance such as tire marks, livestock activity or large amounts of debris were excluded. Glades adjacent to roads or with other evidence of altered hydrology were also excluded. All sites are located on public land.

Each site was visited at least once in summer 2009 and spring 2010. The total boundary of the glade and the boundary of the wet-glade were each mapped with the wet glade defined as the boundary of obligate wetland vegetation or standing water. Each area was assigned a habitat code to indicate dry glade (DG), limestone glade seep (GS), limestone glade streamside meadow (SM), or border vegetation (BV). Border vegetation comprised the vegetation along the edge of the open area and the cedar-woodland.

Sites were mapped using ArcMap 9.2 and total area of each habitat type was determined. Photo points were established with GPS coordinates to photo-document each habitat type within each glade. Photographs were taken at eye level (~1.5 m) during each visit so that the entire extent of the glade was photographed each season.

Flora

A floristic inventory was conducted of all vascular plants growing at each site, with nomenclature following Chester et al. (2009). All vascular plant species in flower or fruit at the time of the visit were collected and identified. All species not in flower or fruit that could be identified were recorded as well. A species list noting the habitat type in which each taxon was found was compiled. Wetland codes (Reed 1997) were assigned for all taxa, and frequency of each code was determined for each habitat type. This list was used to compile a complete flora of the seasonally wet cedar glade communities and for comparison against the previously published flora of the limestone glade ecosystem (Baskin and Baskin 2003). The annotated list was organized by plant family within the four major plant groups (ferns and fern allies, gymnosperms, angiosperms: dicots, angiosperms: monocots). Each entry in the checklist includes the scientific name, common name, site number(s) where found, habitat code (DG, GS/SM or BV), statement of abundance, wetland code, biogeographical affinity and collection number of specimens retained at APSC. Endemic, rare and exotic species were also noted.

Voucher specimens were collected and deposited in the Austin Peay State University Herbarium (APSC), with duplicates distributed to the University of Tennessee Herbarium (TENN) for Tennessee specimens and Eastern Kentucky University Herbarium (EKY) for Kentucky specimens.

Vegetation

Community analysis of vascular plants was performed at all sites using methods modified from the Photographic Method described by Wimbush et al. (1967). At each site, one 15 m transect was laid down the long axis of each GS and SM habitat type, as well as down the long axis of the adjacent DG habitat type. Five 0.5 m x 1 m quadrats were randomly placed on alternating sides of each transect. Photographs of each quadrat were taken from approximately 1.2 m above the ground using a Casio Exilm S-10, 10.1 megapixel camera. These photographs were later used to determine percent cover for all vascular plants, water, soil, exposed rock, cyanobacteria (*Nostoc* sp.), and bryophytes using the area-list method with a dot-grid overlay (Bonham 1989). Analysis of photographs was performed using Gimp image manipulation software version 2.6. To verify the legitimacy of this method, in spring 2010, each quadrat was also examined in the field. Percent cover data were recorded for all species and cover types. Data collected using both methods were compared using a paired *t*-test to determine precision of the photographic method (JMP). Cluster analysis was also performed on quadrats using percent cover data (JMP).

Soil

At each site, soil pH and depth were measured at three random points within each habitat. The soil series of each site was also assessed using county soil maps.

Hydrology

Physical signs of hydrology such as water marks, sediment deposits and algal mats were recorded and photo documented. When evident, the source of the hydrologic charge for the wetlands (groundwater, spring-fed, rainwater runoff, etc.) was also documented.

CHAPTER 3

RESULTS

Site Characteristics

Ten study sites were selected with three sites in Simpson County, Kentucky, one in Davidson County, Tennessee, four in Wilson County, Tennessee and two in Rutherford County, Tennessee (Fig. 3.1). The mean study site area was 0.37 ha, and the mean GS/SM habitat area was 0.15 ha (Table 3.1). Mean soil depth was 7.9 cm in the GS/SM habitat, and 5.6 cm in the DG habitat. Soil pH was circumneutral with a mean of 6.8 in the GS/SM areas and 6.9 in the DG areas. Seven sites had apparent hydrological inputs from overflow from adjacent ephemeral streams, three from groundwater seepage, and one was spring fed.

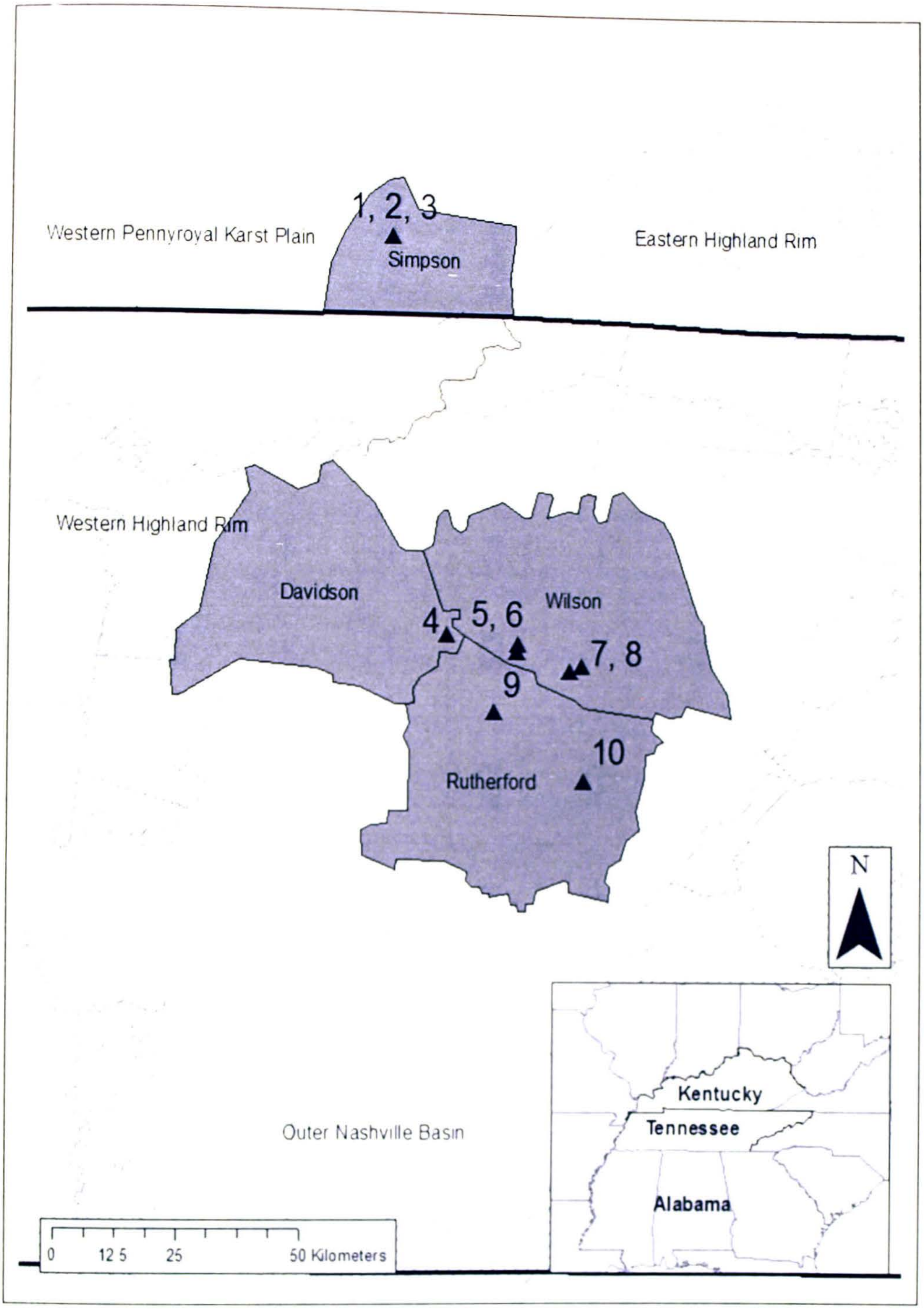


Figure 3.1 – Location of study sites in southern Kentucky and central Tennessee. (1, 2, 3-Flatrock Glade Nature Preserve, Simpson Co., Kentucky; 4-Couchville Cedar Glade State Natural Area, Davidson Co., TN; 5-Cedar of Lebanon State Natural area Glade S46, Wilson Co., Tennessee; 6-Cedars of Lebanon State Forest Glade 139, Wilson Co., TN; 7-Cedars of Lebanon State Forest Glade 137, Wilson Co., TN; 8-Cedars of Lebanon State Forest Glade 138, Wilson Co., TN; 9-Sunnybell Glade State Natural Area, Rutherford Co., TN; 10- Overbridge Cedar Glade State Natural Area, Rutherford Co., TN.

Table 3.1 – Summary of physical characteristics of study sites (USDA 2010).

Site	County, State	Coordinates	Elevation (m)	Area (ha)			Mean Soil Depth (cm)		Soil pH		Water Source	Soil Series
				GS/SM	Total	% Total	GS/SM	DG	GS/SM	DG		
1	Simpson Co., KY	36.84877 N, 86.63142 W	180	0.08	0.08	100	8.4	---	7	---	Groundwater seepage	FdC
2	Simpson Co., KY	36.8517 N, 86.63493 W	180	0.03	0.11	27.3	---	---	---	---	Ephemeral Stream	FdC
3	Simpson Co., KY	36.84817 N, 86.63204 W	180	0.11	0.11	100	---	---	---	---	NA (DG)	FdC
4	Davidson Co., TN	36.10091 N, 86.53543 W	200	0.07	0.38	18.4	5.3	5.5	---	---	Ephemeral Stream	GdC
5	Wilson Co., TN	36.08445 N, 86.40276 W	154	0.4	0.4	100	9.1	---	6.2	---	Spring Fed, Ephemeral Stream	GaC
6	Wilson Co., TN	36.07165 N, 86.40394 W	170	0.07	0.19	36.8	3.4	5.9	---	---	Ephemeral Stream	GaC
7	Wilson Co., TN	36.04717 N, 86.28503 W	167	0.1	0.57	17.5	8.3	6.0	6.8	6.9	Groundwater seepage, ephemeral stream	GaC

8	Wilson Co., TN	36.03782 N, 86.30698 W	158	0.15	0.48	31.3	4.1	8.3	7	6.7	Ephemeral stream	GaC
9	Rutherford Co., TN	35.96837 N, 86.44702 W	174	0.35	1.14	30.7	6.1	7.2	---	---	Groundwater Seepage	GRC
10	Rutherford Co., TN	35.84687 N, 86.28043 W	181	0.06	0.21	28.6	12.9	6.1	6.75	6.9	Proximity to creek	GRC

Flatrock Glade State Nature Preserve, Simpson County, Kentucky

From Bowling Green, KY take US-68 W 17.7 km to Hwy 73. Turn left onto HWY 73 and travel 5.8 km to Hardison Rd. Travel 2.2 km and turn left down unnamed dirt road and travel approximately 590 m. Park on right. The original 14 ha of this 40 ha preserve was dedicated in 1990 and is bordered by cattle pastures and small farms. The preserve is closed to the public and there are no established trails (KSNPC 2010). FNP study site 1 (36.84877 N, -86.63142 W) is a GS community, 0.08 ha in area and is located in the southeast section of the preserve (Fig. 3.2). FNP study site 2 (36.8517 N, -86.63493 W) is a SM community, 0.11 ha in area and is located in the northwest section of the preserve. FNP study site 3 (36.84817 N, -86.63204 W) is a DG community, 0.11 ha in size and is located just off a trail from the parking location in the southern section of the preserve.

Couchville Cedar Glade State Natural Area, Davidson and Wilson County, Tennessee

From Nashville International Airport, travel 14 km on I-40 E. Take exit 226A to TN-171 S. Travel approximately 7.2 km S to parking area on right. Follow trail approximately 650 m west from parking area (36.10091 N, -86.53543 W). This 76.4 ha Natural Area, located in the Tennessee Central Basin, was designated a state natural area by the state of Tennessee in 1995. The site is open to the public and has frequently used walking trails throughout (TDEC 2010). The 0.38 ha study site is located approximately in the center of the natural area adjacent to a trail (Fig. 3.3). A 0.07 ha SM community occurs along an ephemeral stream along the southern edge of the site.

Cedars of Lebanon State Natural Area, Wilson County, Tennessee, Sunnybell 46

This 422 ha natural area is part of the 3739 ha Cedars of Lebanon State Forest (Fig. 3.4). The site was one of the first natural areas, designated in 1974. The land was acquired in 1935 by the Federal Resettlement Administration. The site is open to the public, but there are no public trails throughout the natural area. There are, however, extensive trails developed throughout the adjacent state park. The 336 ha state park is also a popular camping spot (TDEC 2010). From Lebanon TN, travel approximately 10.5 km S on US-231. Turn right on Cedar Forest Rd, and travel 5.9 km west. Site approximately 200 m northwest off road (36.08445 N, -86.40276 W). Sunnybell 46 is a 0.40 ha study site located in the southwest portion of the natural area. The entire site is considered a SM community adjacent to an ephemeral stream (Fig. 3.4).

Cedars of Lebanon State Forest, Wilson County, Tennessee, Glade 139

From Lebanon, TN travel approximately 15.3 km S on US-231. Turn right on Vesta Rd. and travel approximately 4.8 km. Turn right on Moccasin Ln. and travel 0.6 km north. Study site is approximately 450 m west down old road, then 115 m north through woods (36.07165 N, -86.40394 W). Glade 139 is a 0.19 ha site located in the southwest section of the state forest, south of the natural area. A 0.07 ha SM community sits in the center of the site (Fig. 3.5).

Cedars of Lebanon State Forest, Wilson County, Tennessee, Glade 137

From Lebanon, TN, travel approximately 11.3 km S on US-231. Turn left at E. Richmond Shop Rd. and travel 4.5 km. Take a slight left onto Cedar Forest Rd. and travel approximately 3.7 km. Study site is approximately 300 m N of road (36.04717 N, -86.28503 W). Glade 137 is 0.57 ha and is located in the southeast section of the state forest. A 0.06 ha GS community runs along the northern edge of the site, and a 0.10 ha SM community runs adjacent to an ephemeral stream on the northeast end of the site (Fig. 3.5).

Cedars of Lebanon State Forest, Wilson County, Tennessee, Glade 138

From Lebanon, TN travel approximately 16.1 km S on US-231. Turn left onto Whippoorwill Rd., and travel 4.3 km. Site is approximately 130 m east of road (36.03782 N, -86.30698 W). Glade 138 is 0.48 ha and is located in the southern portion of the state forest. A 0.02 ha GS community sits on the northeast end of the site, and a 0.13 ha SM community runs adjacent to an ephemeral stream through the center of the site (Fig. 3.5).

Sunnybell Cedar Glade State Natural Area, Rutherford County, Tennessee

From Smyrna, TN travel 11.6 km SE on US-41. Take ramp onto TN-840 E. Take the Sulphur Springs Rd. exit (57) and travel west 1.1 km. Turn right on Buckeye Valley (Buckeye Bottom) Rd. and travel approximately 3.5 km. Park on side of road and cross under hwy through culvert to east side of TN-840. Site is approximately 90 m northwest through woods (35.968368 N, -86.447023 W). This 21.47 ha natural area, located in the Tennessee Central Basin, was designated a state natural area in 1995 and is closed to the public (TDEC 2010). The 1.14 ha study site is located at the northeast end of the natural area (Fig. 3.6). A 0.35 ha GS community is located in the southeast corner of the site.

Overbridge State Natural Area, Rutherford County, Tennessee

From Murfreesboro, TN travel approximately 9 km E on US-70S. Turn left at Coleman rd. Turn right on E. Main St. then immediate left on Cranor Rd. Travel 2.3 km and park on corner just after the Cranor Convenience Center and hike approximately 450 m NW to site (35.84687 N, -86.28043 W). This 40 ha natural area, located in the Central

Basin, was designated a state natural area in 1995. This site is closed to the public. The site was previously part of a cattle farm (TDEC 2010). The 0.21 ha study site is located in the northeast quadrant of the natural area (Fig. 3.7). Two SM communities occur at the site, the first along the north edge of the site 0.01 ha in area and the second, 0.05 ha in area in the southern portion. Adjacent to the site is Dry Creek, a large stream running near the northern border.

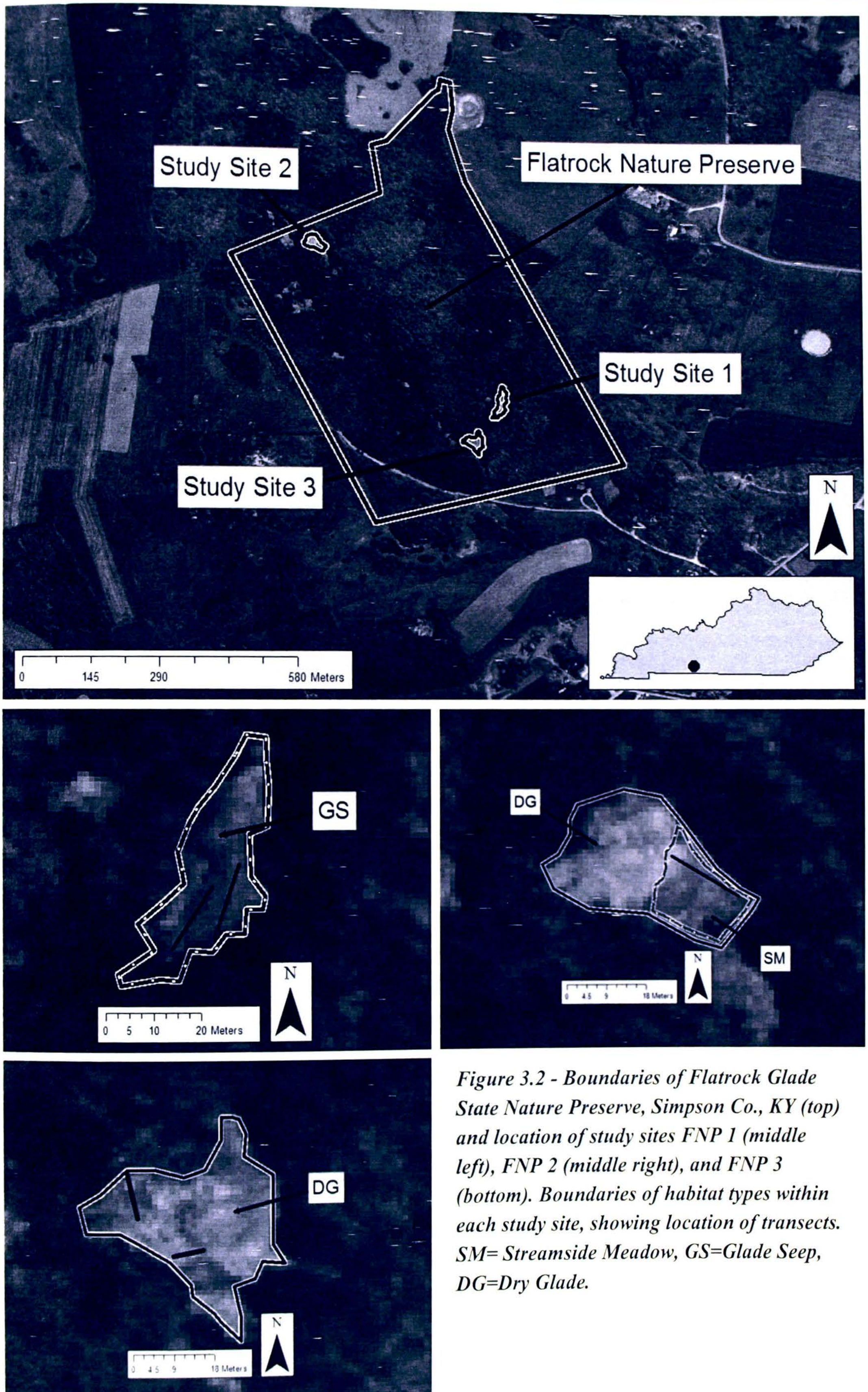


Figure 3.2 - Boundaries of Flatrock Glade State Nature Preserve, Simpson Co., KY (top) and location of study sites FNP 1 (middle left), FNP 2 (middle right), and FNP 3 (bottom). Boundaries of habitat types within each study site, showing location of transects. SM= Streamside Meadow, GS=Glade Seep, DG=Dry Glade.

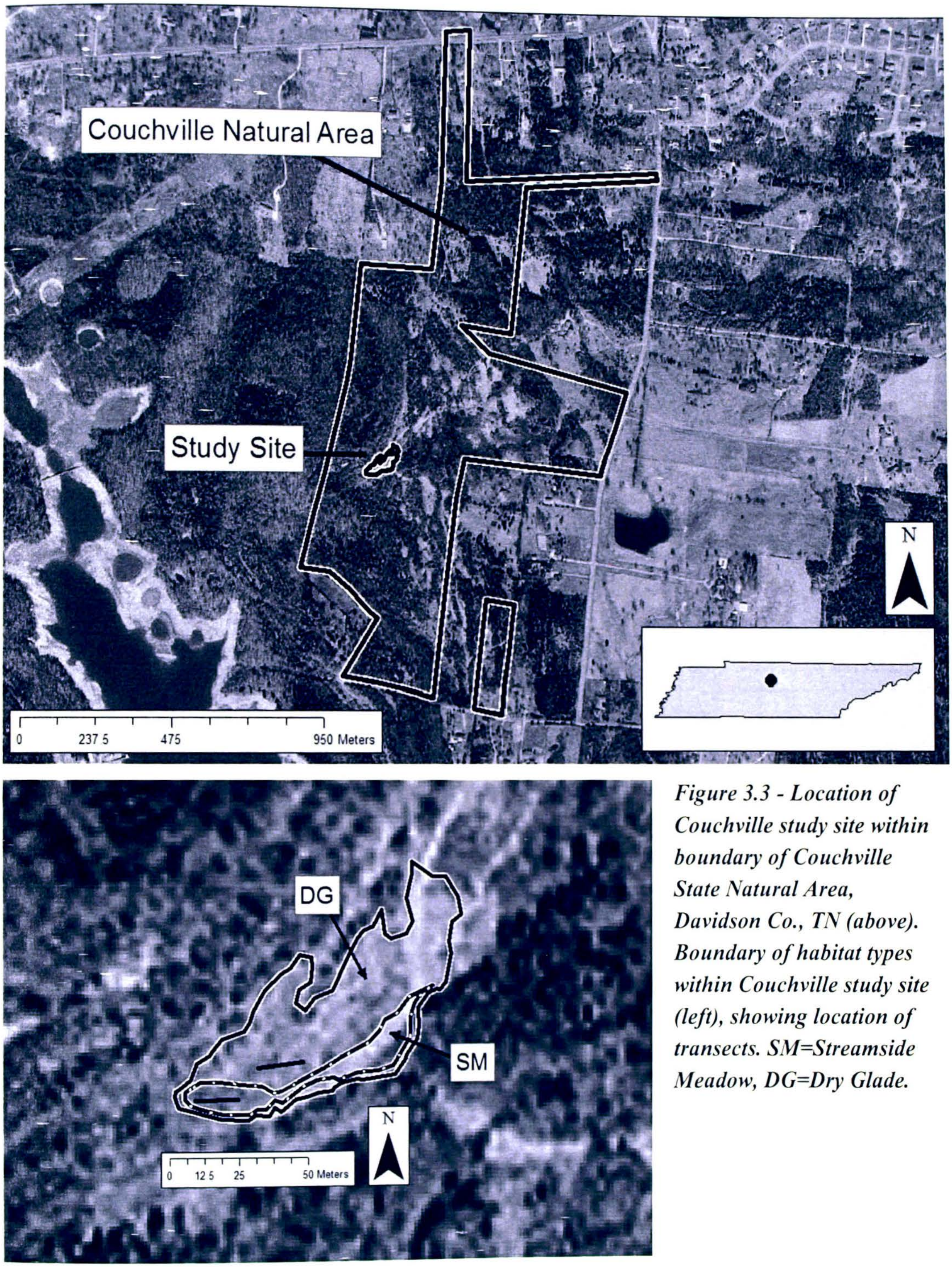
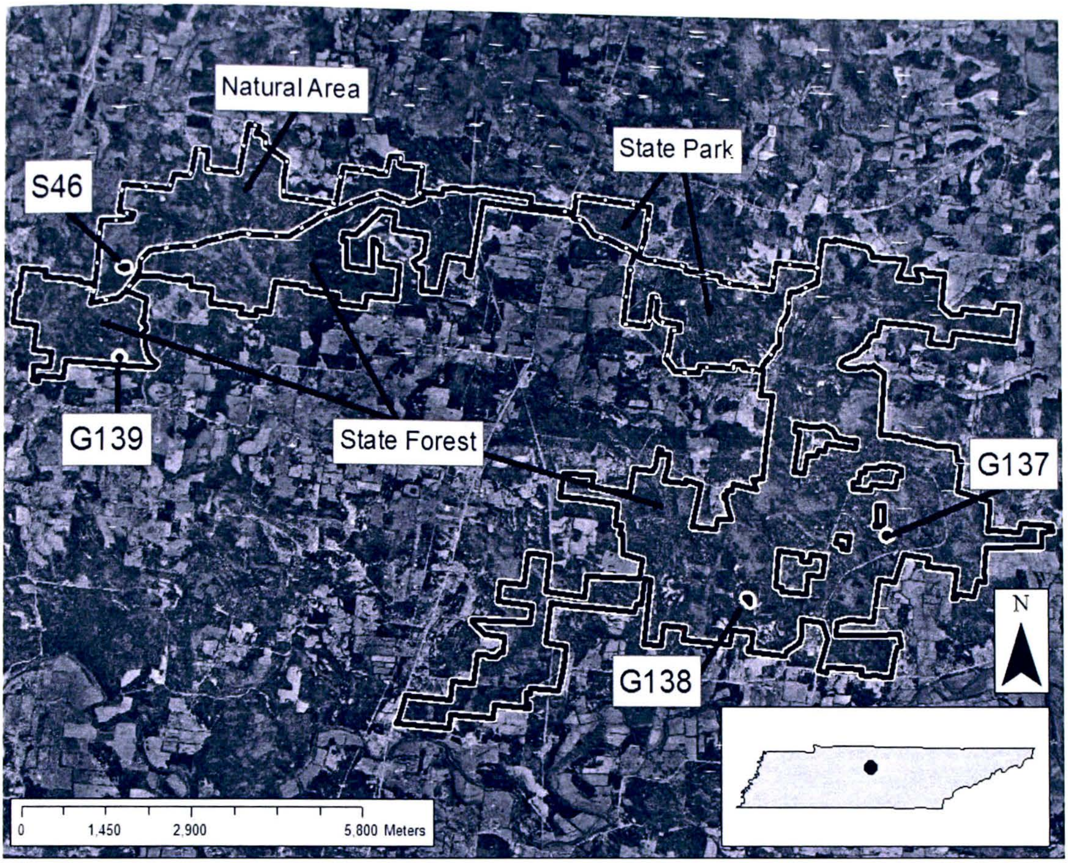


Figure 3.3 - Location of Couchville study site within boundary of Couchville State Natural Area, Davidson Co., TN (above). Boundary of habitat types within Couchville study site (left), showing location of transects. SM=Streamside Meadow, DG=Dry Glade.



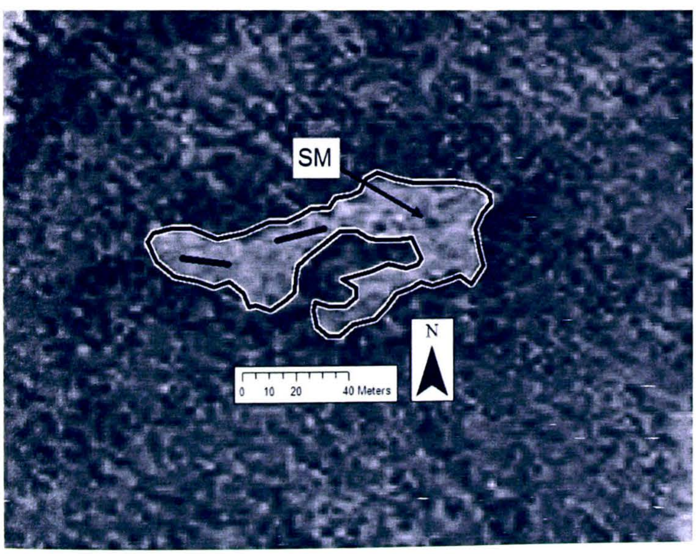


Figure 3.4 - Boundaries of Cedars of Lebanon State Park, Natural Area and Forest, Wilson Co., TN (above) and location of study sites Sunnybell 46 (S46), Glade 137 (G137), Glade 138 (G138) and Glade 139 (G139). Boundary of habitat types within study site S46 (left), showing location of transects. SM= Streamside Meadow.

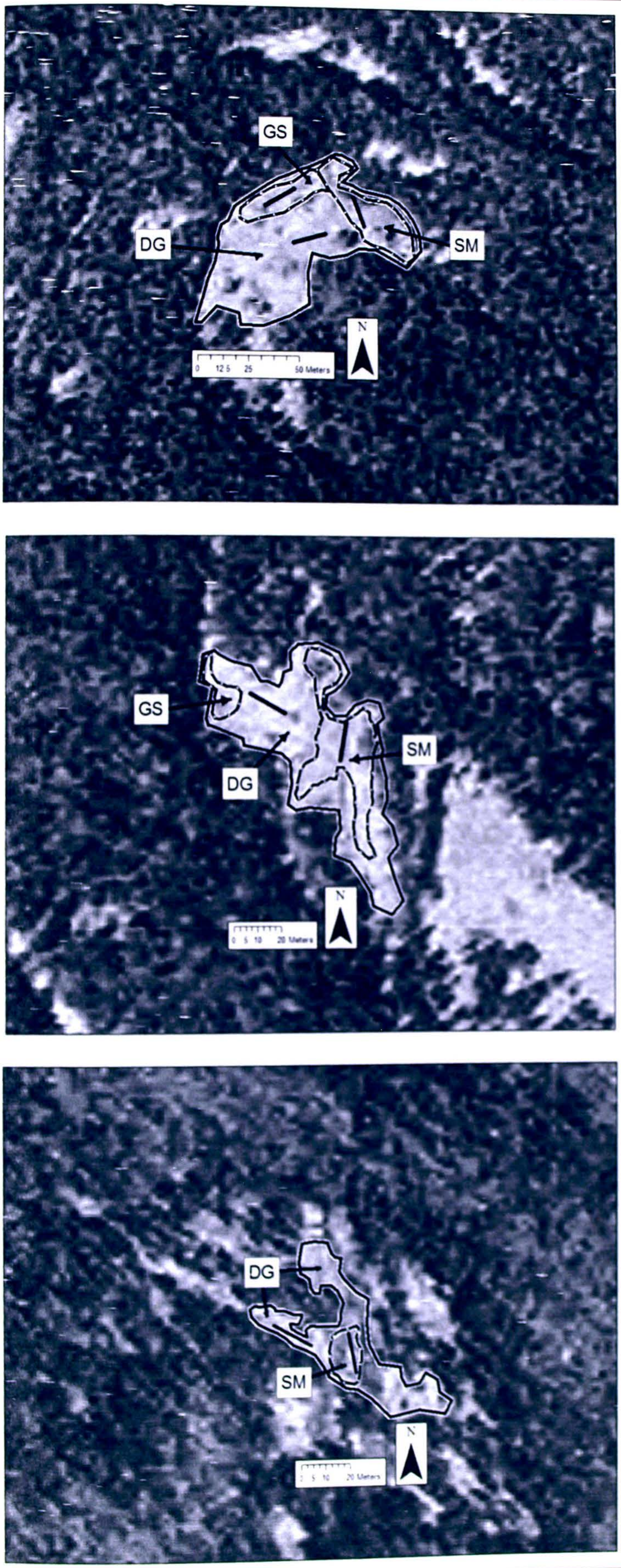
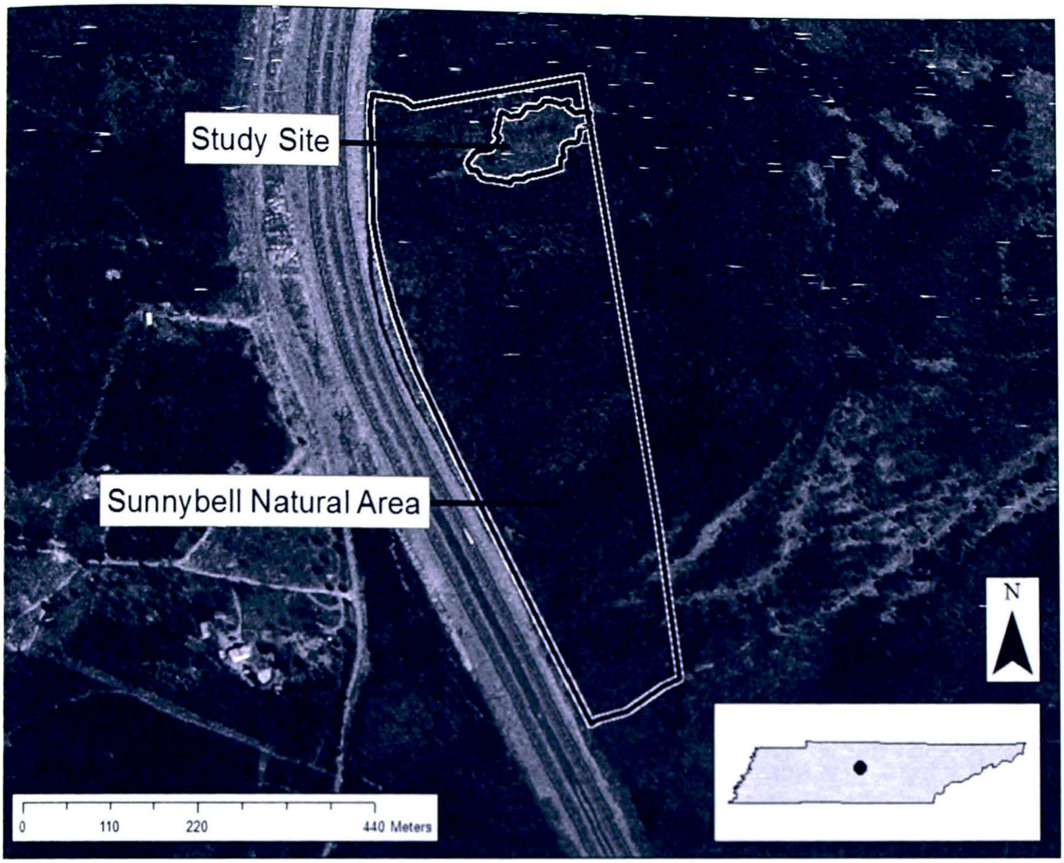


Figure 3.5 – Boundaries of study sites within Cedars State forest. Hbitat types and location of transects within study site Glade 137 (top), Glade 138 (middle) and Glade 139 (bottom). All three sites are located in Cedars of Lebanon State Forest, Wilson Co., TN. SM=Streamside Meadow, GS=Glade Seep, DG=Dry Glade.



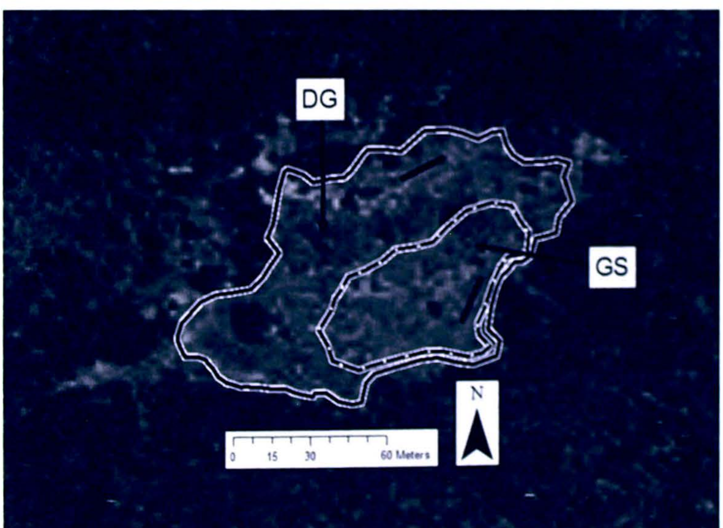
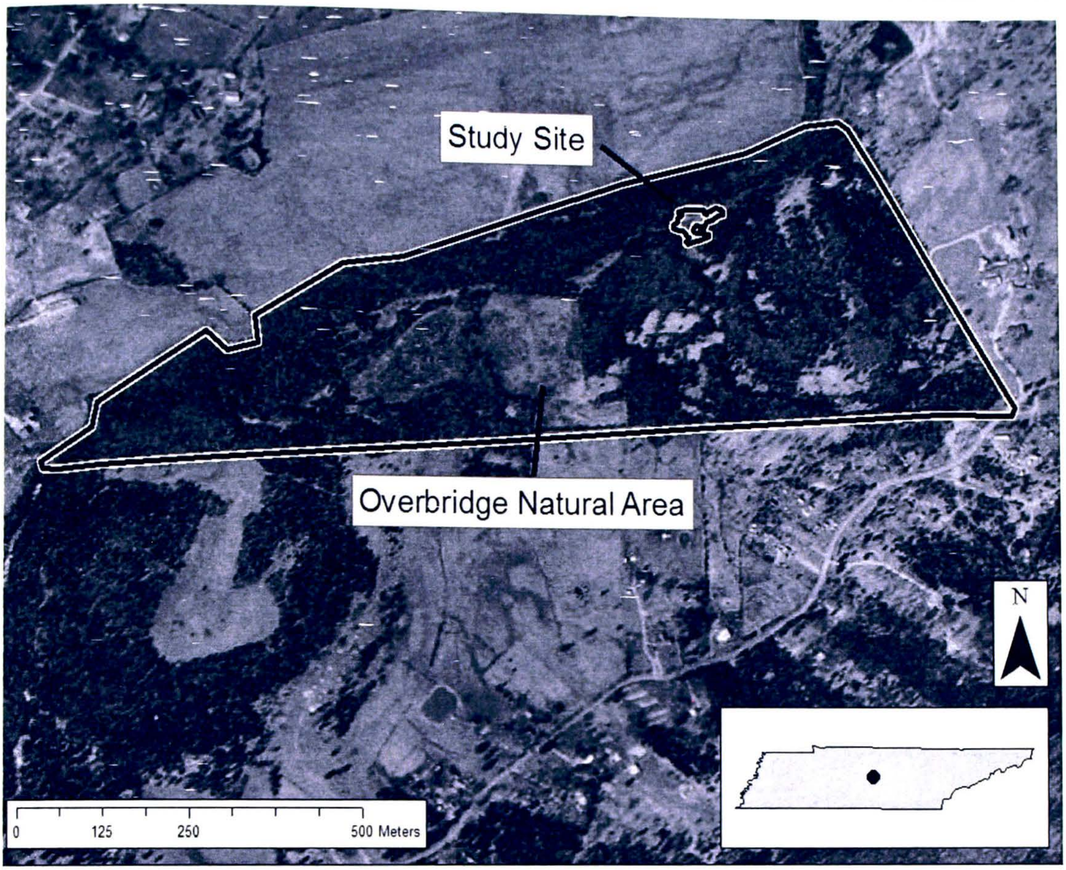


Figure 3.6 - Location of Sunnybell study site within Sunnybell State Natural Area, Rutherford Co., TN (above). Boundary of habitat types within Sunnybell study site (left), showing location of transects. GS= Glade Seep, DG=Dry Glade.



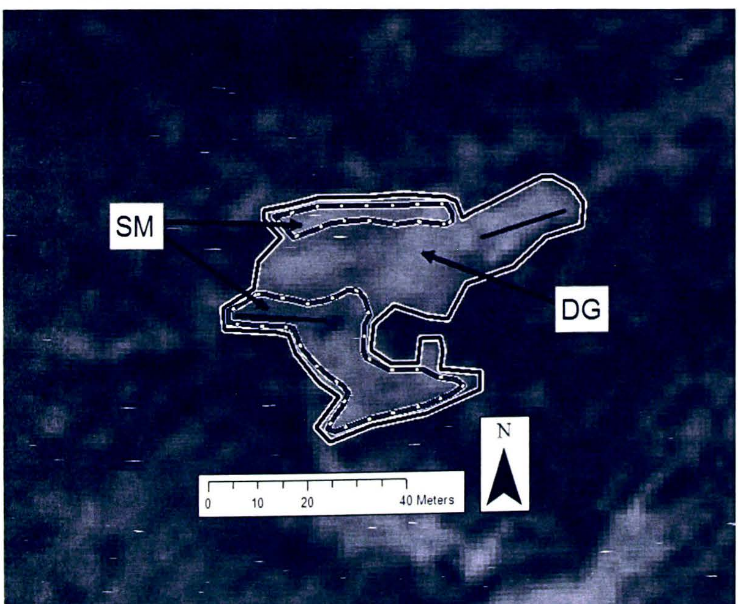


Figure 3.7 - Location of Overbridge study site within Overbridge State Natural Area, Rutherford Co., TN (above). Boundary of habitat types within Overbridge study site (left), showing location of transects. SM=Streamside Meadow, DG=Dry Glade.

Floristic Analysis

A total of 159 species and infraspecific taxa were documented from the ten study sites, representing 131 genera and 60 families. The 159 taxa were distributed among 4 pteridophytes, 1 gymnosperm and 154 angiosperms divided into 43 monocots and 111 dicots (Table 3.2). A total of 100 taxa were identified from the GS/SM habitats, 94 from the DG habitat and 47 from the BV habitat. Of these, 33 were exclusively found in the GS/SM habitat, 22 exclusively from the DG habitat and 28 exclusively from the BV habitat.

Asteraceae and Poaceae were the largest families with 19 taxa each, followed by Euphorbiaceae (9), Fabaceae (9), Cyperaceae (8), and Lamiaceae (6). The largest genus was *Carex* with 4 taxa, followed by *Asclepias*, *Chamaesyce*, *Dichanthelium*, *Hypericum,* and *Leavenworthia,* each with 3 taxa. Sixteen woody species were documented from the BV habitat with 9 trees, 6 shrubs and 1 liana. Taxa were divided into 103 perennials, 40 annuals, 1 biennial and 13 taxa which are variable with respect to duration (Table 3.3). Additionally, 20 taxa not included in Baskin and Baskin's flora of the glades were documented in this study. See Appendix A for a complete list of taxa found.

Ten non-native taxa were documented representing 6.25 percent of the total flora. Five of the 10 non-native taxa are listed as invasive in Tennessee, Kentucky or both (Table 3.4) (TN-EPPC 2009, KY-EPPC 2008). Among the native flora represented, 17 species (10.6 percent) are listed as rare at the state or federal level (Table 3.5) (Crabtree 2008, KSNPC 2006). Of the 150 native taxa, 93 had an intraneous distribution with14 of these endemic to cedar glades (Table 3.6). A total of 50 taxa had extraneous distributions with 27 extraneous to the west, 15 to the north and 8 to the south. Five additional taxa were disjunct from the west.

Table 3.2 - Summary of the vascular flora of seasonally wet limestone cedar glades. Numbers in parentheses refer to number of taxa from within the seasonally wet community.

			Species and Infraspecific Taxa		
Group	**Families**	**Genera**	**Native**	**Non-native**	**Total**
Pteridophytes	4	4	4	0	4 (2)
Gymnosperms	1	1	1	0	1 (0)
Angiosperms					
Monocots	10	32	41	2	43 (32)
Dicots	45	94	103	8	111 (66)
Total	**60**	**131**	**149**	**10**	**159 (100)**

Table 3.3 - Breakdown of life forms for the 159 taxa documented from the ten study sites.

Annual vs. Perennial	**Number of Species**
Perennial	103
Annual	41
Annual Perennial	5
Annual Biennial	3
Biennial Perennial	3
Annual Biennial Perennial	2
Biennial	1

Table 3.4 - List of exotic taxa documented during the study. Alert = taxon possesses invasive characteristics and is known to be invasive in other states; Lesser Threat = Not presently considered a threat to native communities but spread in disturbed areas; Significant Threat = Taxon possesses invasive characteristics, but does not spread as easily as Severe Threat; Severe Threat = Taxon possesses invasive characteristics and spreads easily into native communities displacing native vegetation (TN-EPPC 2009, KY-EPPC 2008).

Exotic Species	TN Ranking	KY Ranking
Bromus commutatus	---	---
Cardamine hirsuta	---	---
Chamaesyce prostrata	---	---
Commelina communis	---	Lesser Threat
Daucus carota	Alert	Significant Threat
Lespedeza cuneata	Severe Threat	Severe Threat
Leucanthemum vulgare	Alert	Significant Threat
Ligustrum sinense	Severe Threat	Severe Threat
Portulaca oleracea	---	---
Trifolium campestre	---	---

Table 3.5 - Rare vascular plant taxa documented from seasonally wet cedar glades. (Crabtree 2008, KSNPC 2006). Taxa occurring within the seasonally wet community are indicated with an asterisk (*).

Species	Tennessee Status	Kentucky Status	Federal Status
**Bouteloua curtipendula*	---	S[1]	---
**Carex crawei*	---	S	---
**Dalea foliosa*	E[2]	NR[4]	E
Delphinium carolinianum ssp. Calciphilum	---	T[3]	---
Echinacea tennesseensis	E	NR	E
Forestiera ligustrina	---	T	---
**Isoetes butleri*	---	E	---
**Juncus filipendulus*	---	T	---
**Leavenworthia torulosa*	---	T	---
**Lobelia appendiculata var. gattingeri*	---	E	---
**Oenothera macrocarpa*	T	NR	---
Phemeranthus calcaricus	S	E	---
Phlox bifida ssp. *stellaria*	T	E	---
**Schoenolirion croceum*	T	NR	---
Symphyotrichum priceae	---	T	---

[1]- Special Concern, Underlined symbols indicate taxon was found in the indicated state.

[2] – Endangered

[3] – Threatened

[4]- Not reported to occur in the state

Table 3.6 - Biogeographical breakdown of native taxa documented. Numbers in parentheses indicate number of taxa documented from within the seasonally wet community.

Center of Distribution	Number of Taxa
Intraneous	**92 (54)**
Endemic	14
Extraneous	**50 (38)**
East	0
West	27 (22)
North	15 (12)
South	8 (4)
Disjunct	**5 (4)**
West	5

Vegetation Analysis

Comparison of Field and Photographic Methods

A paired *t*-test was performed to compare percent cover values collected in the field to those collected from the photographic method. There was no significant difference between percent cover values for field values versus photographic values (t=0.35992, DF=558, P=0.7190). A paired *t*-test blocked by cover classes was performed on the 59 field cover classes identified. A cover class was identified as any taxon or abiotic element (i.e. rock) occurring within the quadrat. Of the 59 total classes, 9 showed significant differences between field and photographic methods for percent cover data ($p<0.05$) (Table 3.7).

Table 3.7 - Species and infraspecific taxa determined to have a significant difference between mean percent cover data collected in the field versus the photographic method based on a paired *t*-test blocked by cover class. Of the 59 classes assessed, 50 were determined to have no significant difference between percent cover data collected from the different methods.

Cover Class	Mean Field Cover	Mean Photo Cover	DF	*P*
Croton sp.	1.77	0.54	12	0.011
Eleocharis bifida	44.45	50.12	32	0.0001
Houstonia purpurea var. calycosa	2.93	2	12	0.033
Hypericum sphaerocarpum	11.27	10.03	32	0.018
Leucospora multifida	5.81	2.27	10	0.0001
Lobelia appendiculata var. gattingeri	1.7	0.57	22	<0.0001
Minuartia patula	5.14	2.21	13	0.0014
Pediomelum subacaule	13.3	9.5	9	0.0143
Sedum pulchellum	2	0.5	5	0.0301

Cluster Analysis

Vegetation analysis was completed for both spring and summer. A total of 36 transects were analyzed for spring and summer with 19 and 17 transects respectively. This included 180 total quadrats with 95 from the spring and 85 from the summer. A total of 1010 cover classes were identified and recorded, 559 of which were from the spring with 48 unique cover classes; 451 were from the summer with 39 unique cover classes. A total of 65 unique cover classes were identified between the spring and summer data. A Hierarchical Cluster Analysis (Ward Method) was performed in JMP 8 comparing percent cover values between quadrats. Resulting Dendrogram of the relationships between quadrats for both spring and summer data are shown in Figs.3.8 and 3.9 respectively. Mean percent cover values by site are given in Appendix B.

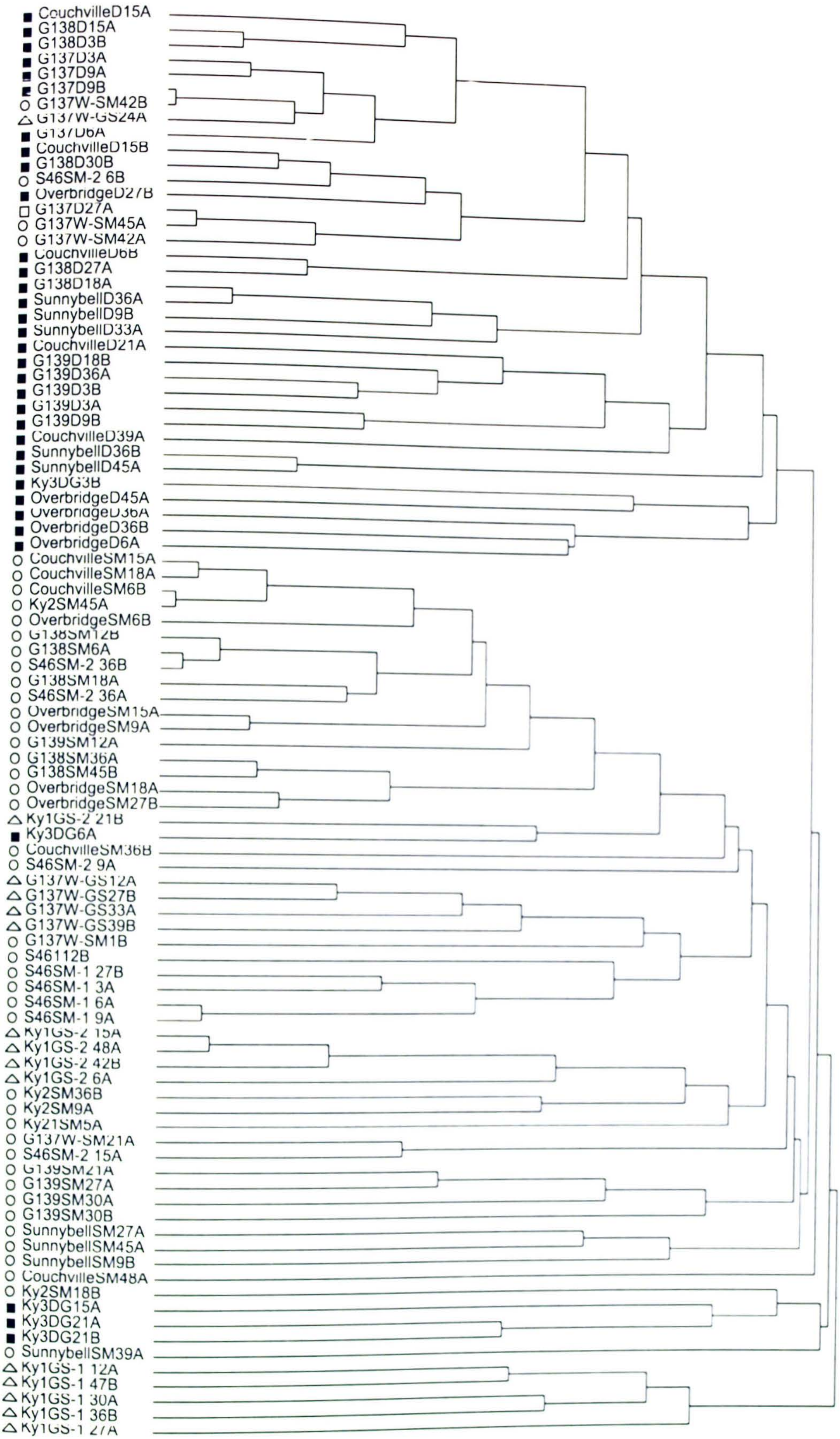


Figure 3.8 - Dendrogram of spring vegetation quadrats. Square – DG habitat, Circle – SM habitat, Triangle – GS habitat.

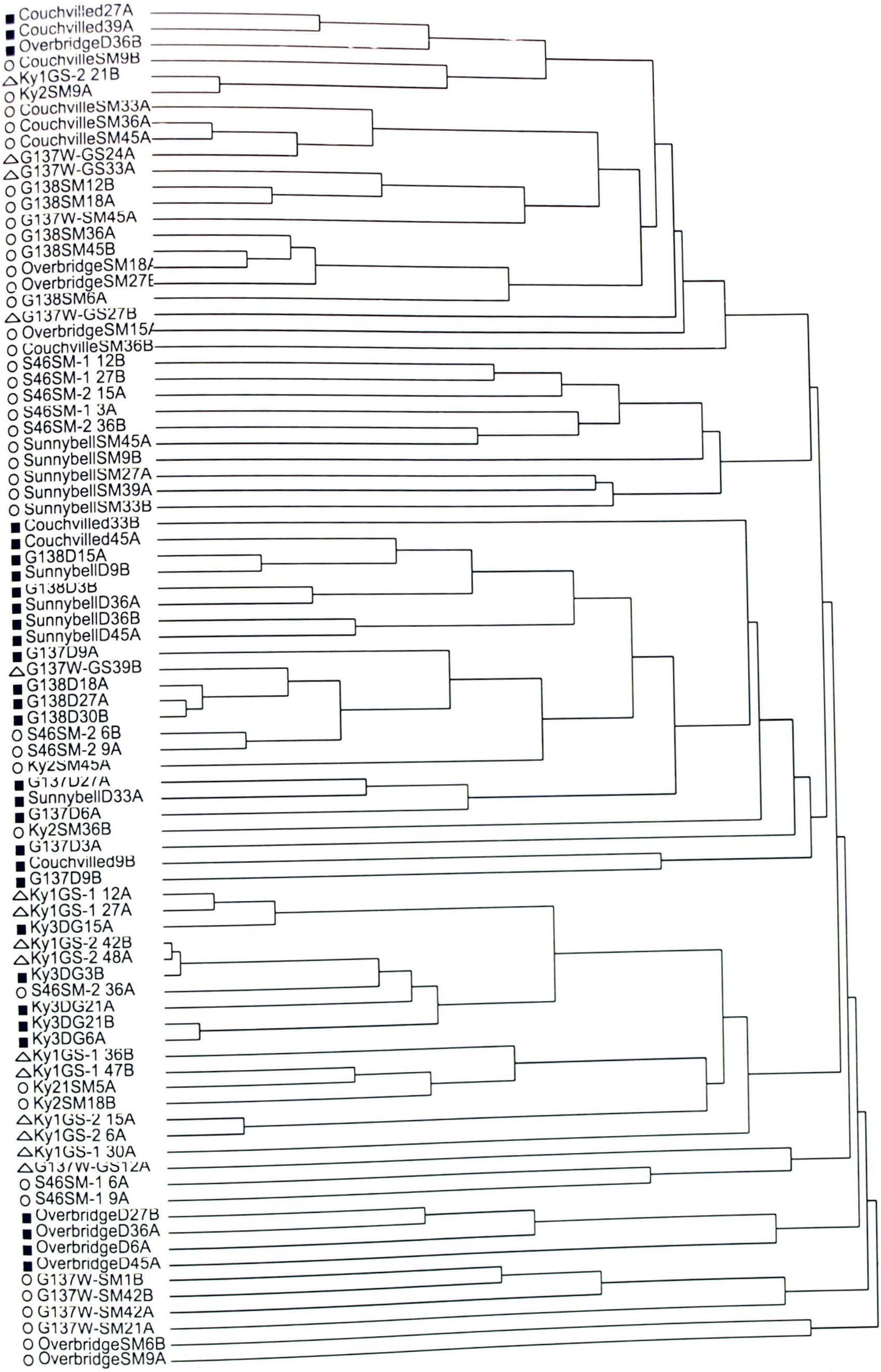


Figure 3.9 - Dendrogram of summer vegetation quadrats. Square – DG habitat, Circle – SM habitat, Triangle – GS habitat.

CHAPTER 4

DISCUSSION

Floristic Analysis

The uniqueness of the cedar glade community is due to the distinctive flora it possesses. A total of 101 taxa were documented from within the seasonally wet community, 21 of which were found exclusively in this community. Of the 101 total taxa documented from seasonally wet cedar glades, 12 of these are listed as rare, and 16 are endemic to cedar glades. Two taxa listed as rare in Kentucky were found exclusively in the wet habitats, the state endangered *Isoetes butleri,* and the state threatened *Juncus filipendulus.*

Rare Plants

Seventeen state or federally listed taxa were documented during this study (Crabtree 2008, KSNPC 2006). Four of these species*, Schoenolirion croceum, Carex crawei, Isoetes butleri* and *Juncus filipendulus* occur as important members in the seasonally wet communities. Restricted to four study sites in Tennessee, *S. croceum* is often a dominant species in seasonally wet communities where it occurs. This taxon grows in the wettest portions of the site, typically in standing water or saturated soil.

Carex crawei and *Juncus filipendulus* are often dominant in these communities as well. *Juncus filipendulus* was found at all but two sites and was a conspicuous member of the community anywhere it occurred. This taxon was found growing across the entire wet community, typically interspersed with *C. crawei* and *Eleocharis bifida. Carex crawei* was also a consistent member of the seasonally wet areas, occurring in all but two sites. This taxon was not as common as *J. filipendulus* and *Schoenolirion croceum* within the community, with fewer individuals present. *Carex crawei* was also found throughout the entire wet community, though it was not restricted to this community. In addition to occurring in the wettest portions of the site, it was also found in the transitional zones between wet and dry portions of the glade. The soils in these transitional areas were still saturated but the amount of water present was much more variable and more dependent on recent precipitation patters.

Isoetes butleri was found at 2 sites, and was much less abundant than the previously mentioned taxa. The only location where considerable numbers of this taxon were found was at Flatrock Glade in Kentucky. This taxon was typically found in areas with less vegetation than previously mentioned taxa. While *Schoenolirion croceum, Juncus filipendulus* and *Carex crawei* were typically found growing together in dense mats, *I. butleri* was not found growing in these areas. All of the taxa mentioned have leaves similar in appearance. *Isoetes butleri* is the least distinct of these taxa with no above ground reproductive parts. It is possible that this taxon was overlooked where it occurred with other linear-leaved taxa.

Found at only one study site, the federally endangered *Dalea foliosa* is restricted to areas just above ephemeral streams through cedar glades. This taxon did not occur in the wet portions of glades, but was found in proximity to these areas. Identification of seasonally wet communities could aid in the identification of additional populations of this federally endangered taxon.

Additional rare taxa which were expected to occur within seasonally wet cedar glades were not found. In Tennessee, *Leavenworthia exigua* var. *exigua* and *L. exigua* var. *lutea* are listed as state special concern and state endangered, possibly extirpated, respectively. Like other members of the genus *Leavenworthia,* these taxa can occur in wet depressions over rock within cedar glades, though they also occur throughout the glades in areas that are not particularly wet. *Stellaria fontinalis* is listed as threatened in both Tennessee and Kentucky. The Tennessee Rare Plant List indicates *S. fontinalis* occurs in "seeps and limestone creek beds" (Crabtree 2008). This taxon was observed at other locations for this community, though none were found in the sites included within this study. The Tennessee threatened *Arnoglossum plantagineum* was expected in the seasonally wet communities but was also not found. The Tennessee Rare Plant List cites the habitat for this taxon as "moist prairies and marshes" (Crabtree 2008). *Scleria verticillata* occurs is wet prairies and fens and was expected in the wet cedar glade communities. However, this Tennessee special concern species was not found. The lack of these taxa in the high quality sites sampled during this study indicates they are indeed rare.

Endemic Taxa

In addition to *Dalea foliosa,* 14 taxa recognized as endemic to cedar glades were documented in this study. Of these, five are important members of the seasonally wet community. *Allium* sp. nov., is a prominent members of the seasonally wet community and is uncommon outside of this community. *Leavenworthia* spp. are also common in this community though they are poor indicators of the community since they are more widespread throughout the entire open glade system. Nine additional endemic taxa were documented in the study in the DG or BV habitats (Appendix A).

Biogeography

A total of 50 taxa with extraneous distributions and 5 with disjunct distributions were documented in the total flora of seasonally wet cedar glades. Over half of these (27 extraneous, 4 disjunct) had primarily western distributions. Among these taxa are several prominent members of the cedar glade flora. *Croton* spp., *Ruellia humilis, Heliotropium tenellum, Minuartia patula* and *Hedyotis nigricans* all have western distributions and are very common throughout the glades. *Juncus filipendulus, Carex crawei, Isoetes butleri, Hypericum sphaerocarpum, Leucospora multifida* and *Clinopodium glabellum* are all western extraneous taxa which are prominent members of the seasonally wet community. Several other prominent members of the seasonally wet community such as *Gratiola quartermaniae, Clinopodium glabellum, Leavenworthia* spp., *Eleocharis bifida* and *Allium* sp. nov. are endemic to cedar glades and cedar glade-like areas. This combination of western extraneous and endemic taxa makes the flora of seasonally wet cedar glade communities very unique.

Exotic Invasives

A major threat to this flora is the spread of non-native taxa into the community. Non-native taxa often have the ability to colonize a community and displace native flora. This threat is amplified in cedar glade communities since the flora is composed of several species that are restricted to cedar glades due to their low competitive ability. The extreme nature of cedar glades typically restricts the introduction of more competitive species allowing the less competitive species to thrive. If a highly competitive non-native taxon were to be introduced that was capable of surviving in the extreme environment, the effects to native vegetation could be devastating.

Nine non-native taxa were documented in this study. Of these five are listed as invasive in Kentucky and four in Tennessee. *Commelina communis* is given a ranking of Lesser Threat in Kentucky indicating the taxon does not pose a threat to native communities but is commonly found in disturbed habitats (KY-EPPC 2008). The only occurrence of this species was at one site in Kentucky in disturbed areas along a trail on the edge of a glade. This species does not appear to pose a threat to the native glade vegetation.

Daucus carota and *Leucanthemum vulgare* are given a ranking of Significant Threat in Kentucky indicating these species possess invasive characteristics (KY-EPPC 2008). Both taxa are also given a ranking of Alert in Tennessee. A ranking of Alert indicates a taxon is known to be invasive in other states (TN-EPPC 2009). *Daucus carota* is very common in some sites, particularly in deeper soil areas. This taxon seems to be restricted in its ability to inhabit thinner soil areas possibly due to its large tuberous taproot, but was occasionally found in the seasonally wet communities. *Leucanthemum vulgare* was low in numbers but found in almost all sites. This species is widespread but its low numbers do not appear to threaten native vegetation.

Lespedeza cuneata was documented from one high quality site with very little disturbance. This site is one of the four study sites for the rare *Schoenolirion croceum* and the only study site where the federally endangered *Dalea foliosa occurred. Lespedeza cuneata* was found growing approximately 10 meters from the *D. foliosa* colony. Continued spread of *L. cuneata* at this site could pose a severe threat to this federally endangered taxon.

Ligustrum sinense is given a ranking of Severe Threat in both Kentucky and Tennessee (KY-EPPC 2008, TN-EPPC 2009). This ranking is given to the most invasive species. These species possess the ability to spread and invade native habits and displace native vegetation. This shrub species poses a great threat to cedar woodlands and shrub zones where it occurs. Seedlings were seen in open cedar glades but no mature individuals were noted in these areas, presumably because they were killed by drought. Thus the open areas and seasonally wet areas appear safe from this threat but the bordering cedar woodlands and shrub margins are threatened.

The low frequency of invasive taxa documented in this study indicates the relatively natural condition in which these communities remain. The presence of some highly invasive taxa is a reminder that these communities are not safe from destruction. The majority of glade communities are highly disturbed and an estimated 50 percent of total glade land in Tennessee has been lost (Noss et. al 1995). The sites in this study were specifically chosen due to their low level of disturbance. The goal was to document the flora of seasonally wet cedar glades in their presumed natural state. It is important to document a community in its most natural state, since without this knowledge a true understanding of the condition of a community and the threats posed to it cannot be assessed.

Comparison of Kentucky and Tennessee Sites

The 159 taxa identified during this study was not uniform throughout the two states sampled. The three study sites in Kentucky had a total of 94 species distributed among 83 genera and 52 families. Of these, 36 species, 24 genera and 9 families were unique to the Kentucky sites. The 7 study sites in Tennessee had a total of 125 species distributed among 113 genera and 66 total families. Of these, 67 species, 54 genera and 20 families were found exclusively in Tennessee. Only 58 species (36 percent of the flora) were shared between the states. Flatrock site number 1 had the highest species richness of all 10 sites, with 77 total taxa found. Flatrock sites 2 and 3 had the lowest species richness of all the sites, with 25 and 29 species respectively. Species richness in the Tennessee sites averaged approximately 53 species, ranging from 47 to 63 taxa. Of considerable note is the abundance of rare or endemic taxa found exclusively in Tennessee. *Dalea foliosa, Echinacea tennesseensis, Leavenworthia stylosa, Oenothera macrocarpa, Phlox bifida* ssp. *stellaria* and *Schoenolirion croceum* were found exclusively in Tennessee and were often locally abundant. *Leavenworthia torulosa* was the only rare taxon restricted to Kentucky study sites. This taxon is known to occur in Tennessee, despite not finding it in this study.

It is not surprising that there are considerable differences in the floras of the two states. All the sites in Tennessee occur in the Central Basin while the Kentucky sites occur in the Highland Rim. The glades of Kentucky are also disjunct from the glades of the Central Basin by approximately 50 km. The region between the areas lacks suitable rock outcrops and is dense forest in its natural state. Much of the land has also been cleared for agriculture.

Comparison to Previously Published Flora

Baskin and Baskin (2003) performed a complete flora of limestone cedar glades of the southeastern United States, documenting 544 taxa. A comparison of their flora with the flora performed in this study identifies 20 taxa that were not documented in the Baskin and Baskin flora (Table 4.1). Three of these taxa, *Allium* sp. nov., *Clinopodium* *glabellum*, and *Gratiola quartermaniae* were included in the Baskin and Baskin flora under different names. *Allium* sp. nov. was listed under *A. cernuum, C. arkansanum under C. glabellum,* and *G. quartermaniae* under *G. neglecta*. It is important to note, however, that these taxa are distinct and should be included within the glade flora as such. Of the 20 taxa, 19 are native and 1 is non-native. The non-native species, *Chamaesyce prostrata* is not identified as a highly invasive species. This species occurred in 3 sites growing in thin, rocky soil and was not a dominant at any of the sites where it was found. Two new additions to the flora of cedar glades were found in the border vegetation and would not be considered part of the seasonally wet communities, with the exception of *Liparis liliifolia* which was also found in a GS community at Flatrock Glade State Nature Preserve in Kentucky. Two additional species were only found in DG communities and would not be considered members of the seasonally wet community. Seven species were documented exclusively from GS communities and 4 were documented exclusively from SM communities. The remaining 6 species were less specific in habitat preference and found in more than one community type.

Allium sp. nov., an undescribed cedar glade endemic, was the most frequently found addition to the glade flora, occurring in 6 sites. This species was a common component of both SM and GS communities and was observed at many sites throughout central Tennessee while searching for potential sites. This summer perennial was not found in any sites outside of Tennessee, and was not found in G139. G139 was added to the study after the summer flora was conducted but is expected to occur at G139, due to its close proximity to other study sites where it was found. *Clinopodium arkansanum,* the next most frequent species, was found in four sites in Tennessee and was a common component in SM habitats. This species is often confused with the similar species *C. glabellum,* and the two frequently grow together.

Twelve of the 20 new additions to the cedar glade flora were documented from Flatrock Glade SNP in Simpson Co., Kentucky, 10 of which were found exclusively at this location. Further exploration of this natural area may yield additional taxa not yet documented from cedar glades. Six of the 20 additions to the glade flora were documented from site 10, Overbridge Natural area in Rutherford Co., Tennessee. Four of these six were unique to this location. *Gratiola quartermaniae,* described in 2007 was documented from only one site but is expected to occur at several other sites (Estes and Small 2007). This early blooming spring annual grows in standing water and is an important component and possible indicator species of seasonally wet cedar glade communities. This species is easily overlooked as it has often completed its life cycle in early spring before intensive field work for this study began. It is expected that this species is more abundant and wide spread in seasonally wet habitats than this study suggests.

Table 4.1 – List of taxa not previously reported from cedar glades. Species documented during this study that were not previously documented as part of the flora of limestone cedar glades by Baskin and Baskin (2003). *=non-native.

Species	Family	Sites Found	Habitats Found
Allium sp. nov. (*A, cernuum*)[1]	Alliaceae	4,5,6,7,8,10	SM, GS, DG
Clinopodium arkansanum (*C. glabellum*)[1]	Lamiaceae	6,7,9,10	SM, GS, DG
**Chamaesyce prostrata*	Euphorbiaceae	1,8,9	GS, DG
Dichanthelium acuminatum	Poaceae	1,5,6	GS, DG
Carex glaucodea Tuckerman	Cyperaceae	1,3	GS, DG
Conoclinium coelestinum	Asteraceae	1,2	DG
Gaura longiflora	Onagraceae	10	SM
Impatiens capensis	Balsaminaceae	10	SM
Penstemon calycosus	Plantaginaceae	10	SM
Ptelea trifoliata	Rutaceae	10	DG
Dioscorea villosa	Dioscoreaceae	9	BV
Gratiola quartermaniae (*G. neglecta*)[1]	Plantaginaceae	6	SM
Erechtites hieraciifolia	Asteraceae	1	GS
Eupatorium serotinum	Asteraceae	1	GS
Leersia virginica	Poaceae	1	GS
Liparis liliifolia	Orchidaceae	1	GS, BV
Muhlenbergia schreberi	Poaceae	1	GS
Physalis pubescens	Solanaceae	1	GS
Pilea pumila	Urticaceae	1	GS
Solanum ptycanthemum	Solanaceae	1	GS

[1]-indicates taxon was included in the flora of Baskin and Baskin (2003) under another taxon.

Comparison of Field and Photographic Methods

Two sampling methods for determining percent cover of species within quadrats were used to collect data during the spring sampling season. The first method consisted of examination of quadrats while in the field. Approximate percent cover values were recorded based on visual estimation. The second method consisted of photographing quadrats from above, superimposing a grid of 100 dots over the photograph and recording 1-percent cover for the species or cover class each dot intersects. Data obtained from these methods were compared using a paired *t*-test showing no significant difference between methods (t=0.35992, DF=558, P=0.7190).

There were several advantages and disadvantages to each method. Examination in the field was time consuming while in the field, but allowed for up close examination and manipulation of plants to ensure correct identification. Identification by the photographic method was more difficult as manipulation and examination of the plant was limited by the resolution and angle of the photograph. This difficulty in identification as well as the time necessary to examine each dot resulted in over double the time commitment for examination compared to the field method. The photographic method did allow for shorter visits in the field allowing more sites to be visited in a single day. The time frame when the seasonally wet communities could be visited for maximum plants in flower is very narrow. If this period of time is missed, important species may be overlooked. The shorter field visits are also convenient in poor weather situations. Close examination of quadrat photographs revealed a few species that were overlooked while in the field. The photographs also provided a record of the quadrat that can be re-examined at a later date if there is any question about percent cover values.

A paired *t*-test blocked by cover class (species, rock, etc.) was also performed to determine if any individual cover class showed significant differences in percent cover values between the two methods. Nine of the 59 total cover classes (15 percent) were significantly different between methods. Six of these nine species were inconspicuous members of the quadrats with mean percent cover values of approximately 5 percent or less. During field examination, inconspicuous members were typically given 1 percent cover for each individual within the quadrat. When the dot grid overlay was superimposed over the photograph, several of these inconspicuous members did not intersect with a dot and were thus given a percent cover value of 0. *Lobelia appendiculata* var. *gattingeri,* for instance, was present in many quadrats but due to the narrow erect habit of the plant it did not intersect with a dot when the photograph was analyzed. Percent cover values of these taxa appear to be inflated using the field method.

Minuartia patula, a small spindly plant, proved very difficult to see in a photograph, especially in high light situations. Therefore percent cover values are greater using the field method, and the occurrence of this species is believed to be underestimated using the photographic method. *Leucospora multifida* is a small herb typically less than 10 cm in height at the time of sampling. This short plant was often difficult to see in photographs since it was over-towered by taller plants. Thus the photographic method appears to have underestimated the percent cover of this species. *Croton* spp., *Hedyotis purpurea* var. *calycosa,* and *Sedum pulchellum* each had mean percent cover values from both methods of less than 5 percent. The importance of species with less than 5 percent cover is insignificant within a quadrat when the purpose is to establish dominant vegetation. Species in this grouping fall within the likely range of error for both methods.

The photographic method only allocates a percent cover point to a cover class if the majority of that dot intersects the cover class. Species with highly dissected leaves often had dots intersecting a portion of a leaf but the majority of the dot touched another cover class due to the dissected nature of the leaf. There was a tendency to allocate the entire area under a dissected leaf to that species while in the field. This led to possible discrepancies between field and photographic data for these species. *Pediomelum subacaule* has palmately compound leaves with large sinuses between lobes. The large sinuses often intersected with dots, meaning the percent cover point was allocated to something other than *P. subacaule,* while this taxon was allotted the entire area in the field, including gaps between leaflets. The discrepancy noted here is evident with the significantly higher mean percent cover values for the field data. *Hypericum sphaerocarpum* may also fall into this category. The small leaves and spindly habit of the plant left many gaps where dots could occur during photographic analysis, whereas these gaps would not be considered while in the field.

The final species with significantly different percent cover values between methods is *Eleocharis bifida.* This sedge is the only species to show significantly greater percent cover values using the photographic method. Identification of this species is simple if caught at the right time of the season while the spike is still on the plant. This species becomes very difficult to identify, particularly by photograph, if the spike is no longer present on the culm. Without the spike, differentiating this species from other grass and sedge species which it commonly occurs with can be very difficult if close manipulation and examination of the culm shape is not possible. Since quadrat photographs were taken when the spikes were still evident on the culm, identification in photographs was very simple. It is believed that the field method underestimated the abundance of *E. bifida* since it typically grows intermixed with other graminoid species. Visual estimation of a species within a quadrat is very difficult when species appear similar and grow in close proximity. The photographic method allowed the analyst to examine each individual dot that intersected with this species and allocate the percent point accordingly instead of merely approximating percent cover. This resulted in a higher percent cover using the photographic method, and the researcher has more confidence in the accuracy of this method for this species compared to field evaluation.

The non-significant result of the paired *t*-test comparing methods suggests either method would be equally accurate in determining percent cover values within quadrats. The further evaluation of each cover class indicates that this is true for 50 of the 59 classes. The instances where cover values differ for a class can be grouped into 4 categories. The first category includes species that are small, low-growing or inconspicuous. These species are typically underestimated using the photographic method since taller plants can obscure them from view in a photograph. If the quadrat consists of dense vegetation with multiple strata, the lower strata can be obscured and thus underestimated using the photographic method. If these species are important in a study, field analysis should be used.

The second category includes species that cover less than 5 percent of the total area of the quadrat. These species fall within the range of analyst error and either method would be equally appropriate for determining percent cover values. These species may not be included when using the photographic method if a dot does not intersect the species. If documentation of the occurrence of the species is important for the study independent of the cover value, then field analysis should be used.

The third category includes species that have large gaps that fall within the area around the species. Species with dissected leaves, small leaves, spindly branches or a diffuse spreading habit fall into this category. These species do not fill the entire area in which they occur. The photographic method is more accurate in determining absolute percent cover of species in this class since it takes these gaps into consideration when the field method does not.

The fourth category includes graminoids or species with grass-like leaves (i.e. *Allium* spp.). The most appropriate method for these species must be assessed on a case by case basis. If the species within the quadrat grow interspersed but each culm can easily be identified then the photographic method allows for the most accurate estimation of percent cover. If species appear similar and can only be differentiated by close examination of the plant, then the field method should be used.

Percent cover values obtained using the photographic method were used in the vegetation analysis in this study. The goal of vegetation analysis in this study was to determine the dominant vegetation within each quadrat. Uncommon species were not important for establishment of dominants, thus underestimation of these species using the photographic method was not a concern. Species obscured by taller species were also not a concern since most quadrats had only one stratum of herbaceous vegetation with few species being concealed by larger species. Species that were concealed by taller vegetation were uncommon and thus not dominant vegetation within the quadrat. The graminoids (*Carex crawei*, *Eleocharis bifida* etc.) which were common in several of the quadrats were easily distinguishable from one another using the photographic method. The only difficulty was obtaining accurate identification of these taxa to the species level (i.e. *Carex* spp.). In this study each taxon within a quadrat was identified to species in the field before percent cover values were obtained using either method. It is recommended that this be done to ensure a complete and accurate list of species for each quadrat. Since this was done in this study, percent cover values obtained from the photographic method were used for vegetation analysis.

Summer Vegetation

Cluster analysis was performed on percent cover data for both spring and summer. The resulting Dendrogram for summer analysis resulted in 6 major branches (Fig. 4.1). Quadrats in branches 1 and 2 were dominated by *Allium* sp. nov. and bare rock (Table 4.2). Branch 1 and 2 were differentiated from one another by *Allium* sp. nov. cover of 37 to 50 percent and 11 to 37 percent respectively.

Branch 3 was characterized by Rock cover of 24 to 45 percent with *Sporobolus vaginiflorus* and *Dalea gattingeri* co-dominating with 10 to 35 percent each. The presence of *Oenothera macrocarpa* and *Grindelia lanceolata* in these quadrats was unique to branch 3. Branch 4 quadrats were dominated by *Eleocharis bifida* at 31 to 55 percent, *Panicum gattingeri/flexile* and *A.* sp.nov. at 5 to 16 percent each. Branch 5 is characterized by the presence of *P. gattingeri/flexile* but a lack of *E. bifida* and *Allium* sp. nov.

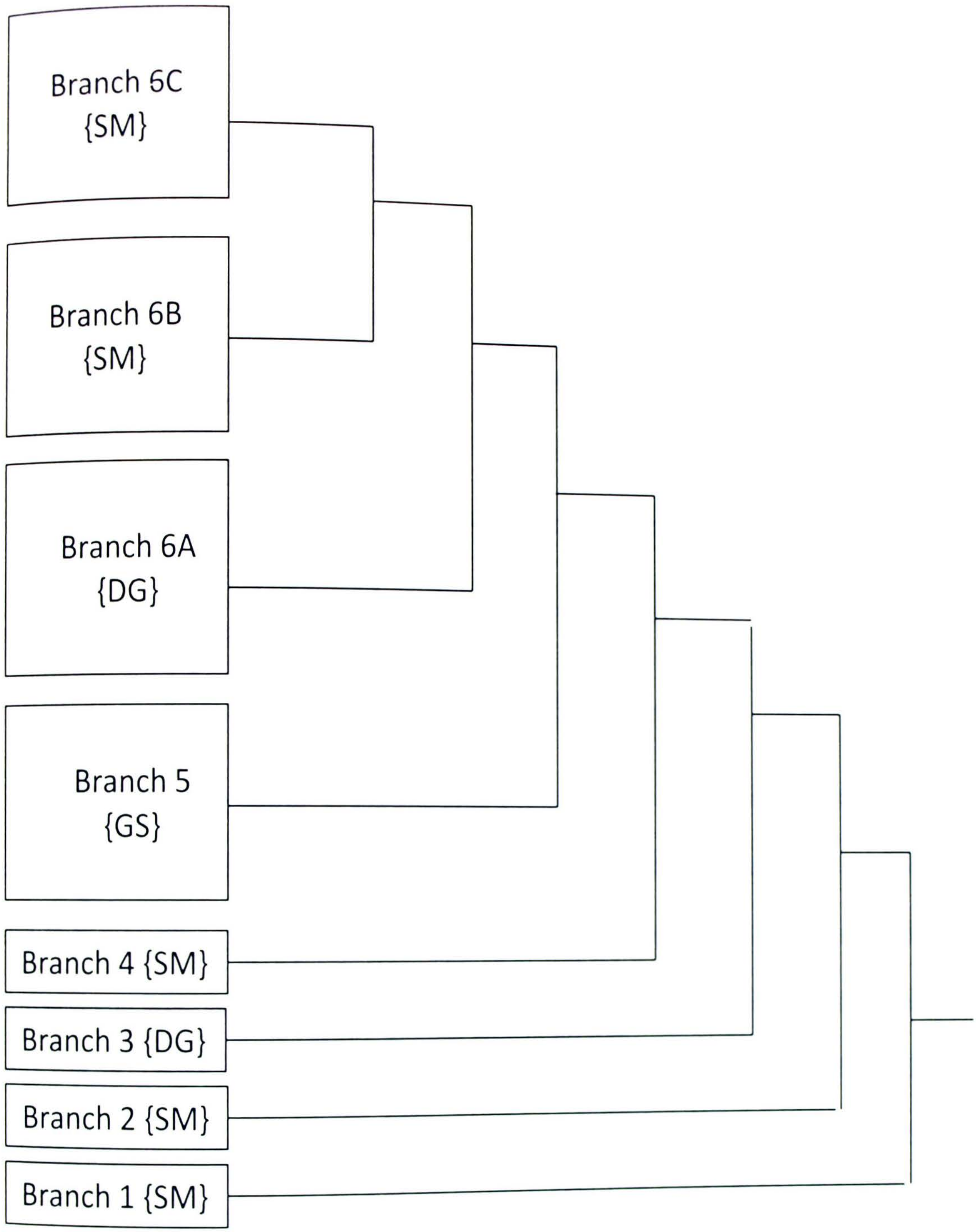


Figure 4.1 - Schematic displaying the hierarchy of branch groupings from cluster analysis of summer vegetation data. Habitat codes most representative of the quadrats within the branch are noted in brackets. Larger boxes indicate more quadrats within the branch.

Table 4.2 - Dominant and characteristic taxa distinguishing branches of summer cluster analysis.

Branch Number	Dominant or Characteristic Taxa
1	*Allium* sp. nov. 37-51%
2	*Allium* sp. nov. 11-37%
3	*Sporobolus vaginiflorus, Dalea gattingeri, Oenothera macrocarpa, Grindelia lanceolata*
4	*Eleocharis bifida, Panicum flexile/gattingeri, Allium* sp. nov.
5	*Panicum flexile/gattingeri*
6A	*Sporobolus vaginiflorus, Dalea gattingeri Panicum flexile/gattingeri*
6B	*Sporobolus vaginiflorus, Panicum flexile/gattingeri, Eleocharis bifida*
6C	*Sporobolus vaginiflorus, Allium* sp. nov.

Branch 6, the largest of the branches is divided into three sub-branches (A-C). Branch 6 is characterized by an abundance of rock, with *Sporobolus vaginiflorus* as the dominant vegetation. The percent cover of rock and *S. vaginiflorus* combined with the co-dominant species differentiates the three sub-branches. Co-dominants of branch 6A, B and C include *D. foliosa* and *P. gattingeri/flexile*, P. *gattingeri/flexile and E. bifida*, and *Allium. sp. nov.*, respectively.

The 6 branches delineated during cluster analysis do not clearly correlate with any habitat types (DG, SM, GS) assigned to quadrats prior to cluster analysis. Some grouping by habitat type is evident though. Branches 1, 2, 4 and 6B are comprised solely of SM quadrats. Branch 3 is comprised solely of DG habitats. Branch 5 is dominated by GS quadrats with 9 of the 15 as such. Branch 6A has 13 out of 23 quadrats as DG. Branch 6C has 15 of its 22 quadrats as SM quadrats. With these results, branches 1, 2, 4, 6B and 6C correspond best with the SM habitat. Branch 5 corresponds best with the GS habitat and branches 3 and 6A correspond best with the DG habitat.

If habitat types are assigned to branches in this manner, the seasonally wet habitat types do not group together. If branches 1 through 4, the first branches to separate out, are not included in this analysis some relationships between habitat types can be seen. The SM habitat (branches 6A and B) and DG habitat (branch 6A) pair together. These combined pair with the GS habitat (branch 5). The exclusion of branches 1 through 4 is not justified however, as the quadrats belonging to these groupings belong to transects with quadrats in other branches. Five transects are represented in branches 1 through 4, but none of these includes all quadrats within that transect among those branches.

The inconclusive nature of the summer cluster analysis is not surprising. All three habitat types are typically dry during the summer months. The seasonal saturation that makes the GS and SM communities unique no longer persists. It would be expected that without the controlling influence of water, the vegetation would not differ between the three habitat types. Factors other than water would be expected to have more influence over vegetation during these drier months. Previous community classifications within cedar glades typically correspond to soil depth. Soil depth was not considered during the differentiation of the GS, SM and DG habitat types and may explain the hierarchy of the summer cluster analysis more accurately than presence of water. If the SM and GS habitat types are distinct communities from the DG habitat type due to the controlling influence of water, the spring cluster analysis would be expected to show this.

Spring Vegetation

Cluster analysis of the spring percent cover data resulted in 5 major branches (Fig. 4.2). Branches 1 and 2 are characterized and differentiated from the remaining branches due to the sparse vegetation, resulting in high cover values for bare ground (Table 4.3). Unlike other quadrats with sparse vegetation, these quadrats did not have exposed bedrock or gravel. These branches are differentiated from one another by the dominant vegetation. Branch 1 contains the only quadrats with cover values over 25 percent for *Diodia teres*. Branch 2 contains various dominants including *E. bifida, Hypericum sphaerocarpum* and *Ruellia humilis*.

Branch 3 is comprised of a single quadrat with 3 co-dominant species, *Carex crawei, Eleocharis bifida* and *Juncus filipendulus*. Branches 4 and 5 are differentiated from one another by percent cover of rock. Branch 4 has a mean cover of rock of less than 20 percent while branch 5 has a mean rock cover of over 50 percent. Smaller branches within each of these large branches are differentiated by dominant vegetation or the presence of indicator species. Dominant vegetation in branch 4 includes *E. bifida, S. vaginiflorus, H. sphaerocarpum, Scutellaria parvula, Schoenolirion croceum, Allium.* sp. nov., *J. filipendulus, Clinopodium glabellum,* and *C. crawei*. A general trend of *E. bifida* cover is evident within branch 4, with cover values ranging from 0 percent at the base of the branch to 98 percent at the tip.

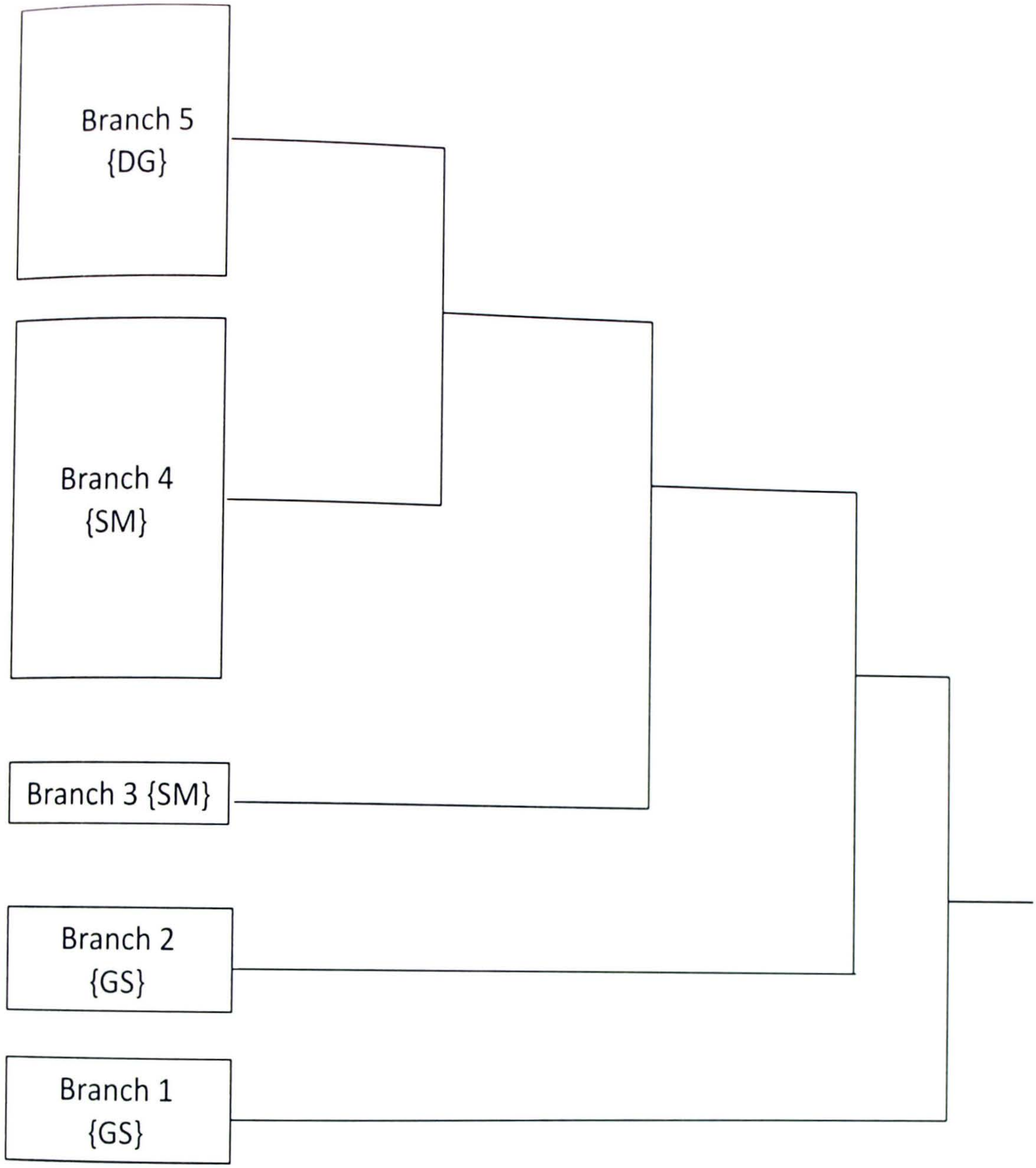


Figure 4.2 - Schematic displaying the hierarchy of branch groupings from cluster analysis of spring vegetation data. Habitat codes which correspond best with quadrats within each branch are noted in brackets. Larger boxes indicate more quadrats within the branch.

Table 4.3 Dominant and characteristic taxa distinguishing branches of spring cluster analysis.

Branch Number	Dominant or Characteristic Cover Classes
1	Bare ground, *Diodia teres*
2	Bare ground, *Eleocharis bifida, Hypericum sphaerocarpum, Ruellia humilis*
3	*Eleocharis bifida, Juncus filipendulus*
4	Rock < 20%, *Eleocharis bifida, Sporobolus vaginiflorus, Hypericum sphaerocarpum, Scutellaria parvula, Schoenolirion croceum, Allium* sp. nov., *Juncus filipendulus, Clinopodium glabellum, Carex crawei*
5	Rock > 50%, *Oenothera macrocarpa, Nostoc commune, Pediomelum subacaule, Arenaria patula, Diodia teres, Croton* spp., *Dalea gattingeri, Allium* sp. nov.

Branch 5 as a whole is differentiated by rock cover greater than 50 percent. As was the case with branch 4, smaller branches within branch 5 are differentiated by dominant vegetation. Dominant species and cover classes important in branch differentiation include *Oenothera macrocarpa, Nostoc commune, Pediomelum subacaule, Minuartia patula, D. teres, Croton* spp., *Dalea gattingeri* and *Allium*. sp. nov..

Unlike the cluster analysis from the summer data, the Dendrogram resulting from the spring vegetation analysis contains a distinct pattern of habitat type distributions. All quadrats within branch 1 are from FNP 1, transect 1. This transect corresponds to a GS community. Branch 2 is comprised of 1 GS quadrat, 1 SM quadrat and 3 DG quadrats. Branch 3 is comprised of a single SM quadrat. Branch 4 is comprised of 13 GS quadrats, 1 DG quadrat and 33 SM quadrats. Branch 5 is comprised of a single GS quadrat, 4 SM quadrats and 31 DG quadrats. Therefore branch 4 is dominated by quadrats from seasonally wet communities (GS and SM), whereas branch 5 is dominated by quadrats from the DG community.

Both branches 1 and 2 are dominated by quadrats from sites in Kentucky. This positioning of these quadrats outside of the remaining quadrat groups suggests the seasonally wet glades of Kentucky may not be equivalent to those of Tennessee. This is not surprising since the flora of the Kentucky sites differed greatly from that of the Tennessee sites. The GS community represented by transect 1 at FNP 1 was superficially very different from any other site in this study. GS communities in Tennessee were laden with gravel and rock, while FNP 1 lacked rock and gravel almost entirely. The cluster analysis supports the idea that this is a unique community type. Branch 2 is similar in its nature to branch 1 as both lack exposed rock. This branch may represent an additional distinct community type that is dominated by denser vegetation, likely resulting from deeper soils.

Branch 3 does not appear to coincide with a unique community type. The quadrat within this grouping is instead believed to be a non-characteristic pocket within another community type. Differentiation of communities is often very difficult in the field as there are pockets within the community that are not representative of the rest of the community. Branch 3 likely corresponds to a non-characteristic quadrat of another community. This quadrat should presumably be nested within branch 4 with the other quadrats from this transect. In addition, the random nature of quadrat selection may have led to the under sampling of quadrats similar to this quadrat. Observations in the field indicated that the vegetation represented in this quadrat was widespread throughout the transect, even though no other quadrats sampled had this combination of dominants.

Branches 4 and 5 are distinct from branches 1 and 2 as well as from one another. Both these branches appear to represent unique community types. The SM and GS quadrats nested within the DG quadrats of branch 5 likely coincide with non-characteristic pockets within the SM and GS community in which they were taken. Field observations noted that several of these quadrats did not appear characteristic of the rest of the community as they had a greater amount of exposed rock than the remaining area. While branch 4 appears to be a unique community type, it does not correspond with a single habitat type. Both GS and SM quadrats are nested within this grouping. The GS quadrats are grouped into two major sections but these sections are nested within branches containing groupings of SM quadrats.

This analysis suggests that the GS and SM designations of habitat codes assigned to sites were incorrect. Instead, all quadrats within branch 4 should be designated with a single habitat code. Comparison of the cover values collected from this study with descriptions of habitats as designated from NatureServe (2009) is necessary to determine the correct habitat designation.

Comparison to NatureServe Communities

The Limestone Seep Glade NatureServe (2009) classification identifies *Eleocharis bifida, Schoenolirion croceum, Carex crawei and Allium cernuum* as dominants with *Nothoscordum bivalve, Isoetes butleri* and *Hypoxis hirsuta* as other characteristic species. The Kentucky Glade Seep classification lists E. *bifida, N. bivalve, I. butleri* and *H. hirsuta* as the dominant vegetation (Table 4.4). The two community types are similar with the main difference being the lack of *S. croceum* in the Kentucky communities. The Limestone Glade Streamside Meadow classification lists *Mecardonia* *acuminata, Dalea foliosa, Mitreola petiolata, Rudbeckia triloba*, and *Ludwigia microcarpa* as dominants as well as various graminoids.

Table 4.4 - Dominant vegetation and characteristic species of three seasonally wet limestone cedar glade communities according to NatureServe (2009). Cluster analysis of spring vegetation data suggests the seasonally wet communities in this study correspond with the Limestone Seep Glade community.

NatureServe Community	Dominant Vegetation and Characteristic Species
Limestone Seep Glade	*Eleocharis bifida, Schoenolirion croceum, Carex crawei, Allium cernuum (=Allium* sp. nov*), Nothoscordum bivalve, Isoetes butleri, Hypoxis hirsuta*[1]
Kentucky Glade Seep	*Eleocharis bifida, Nothoscordum bivalve, Isoetes butleri, Hypoxis hirsuta*[1]
Limestone Glade Streamside Meadow[2]	*Mecardonia acuminata, Dalea foliosa, Mitreola petiolata, Rudbeckia triloba, Ludwigia microcarpa*

[1]-not a dominant in this study
[2]-No examples of this community type were surveyed in this study.

All species listed in the Seep Glade and Kentucky Glade Seep classifications were identified in multiple sites during the study. All species in the SM classification with the exception of *Ludwigia microcarpa* were documented as well. Comparison of these descriptions with the dominant vegetation from quadrats within branch 4 of the spring cluster analysis suggests that branch 4 corresponds more closely with the GS community type. None of the species listed as dominants in the SM NatureServe description were documented as such in any quadrat sampled whereas listed dominants of the GS habitat were common dominants throughout branch 4. As seen in Appendix B, some combination of the species listed in the GS NatureServe description was dominant in almost all quadrats within branch 4.

In addition to the presence of GS dominant species in the spring flora, *Allium* sp. nov., referred to as *A. cernuum* in the NatureServe GS classification, is evident as a summer dominant in many quadrats within branch 4 of the spring analysis. The similarity in dominant vegetation between branch 4 and the NatureServe classification suggests branch 4 quadrats be assigned a GS habitat code.

Found at all but one seasonally wet site, *Juncus filipendulus* was a consistent member of the wet community. *Clinopodium glabellum* or *C. arkansanum* was found in the wet community at all the Tennessee sites. These species should be included in the GS description. An additional species, *Gratiola quartermaniae* was only documented at one study site, but due to its restriction to areas with standing water, serves as a good indicator species for this community. *Hypoxis hirsuta,* listed as a characteristic species of the GS habitat, was not found within the GS habitat. Instead his taxon was typically found in the DG and BV habitats adjacent to the wet communities. This study suggests this taxon should not be included in the description of the GS community. The presence of most of the listed dominants for the SM community type within the study sites suggests these species may be important indicator species for the GS community even if they are not dominant. The lack of these species as dominants in the quadrats sampled suggests the description of the SM community type may need revision.

Designation of habitat codes prior to data analysis was performed based on source of water and proximity to ephemeral streams. All communities adjacent to an ephemeral stream that appeared to be fed by the stream were designated as SM communities. All other seasonally wet sites were designated as GS communities. This differentiation between habitat types does not hold true. As is seen in the cluster analysis in Fig. 3.1, sites not adjacent to streams are nested among sites adjacent to streams. Thus this criterion does not hold as a means of differentiating these community types and revisions to the NatureServe classifications should be made. A merger of the two community types may be necessary. However, though no communities resembling the SM community description were found during this study, it is possible appropriate study sites containing this community were simply not found. Additional search for this community type should be carried out before a merger of the two communities is made.

Regardless of the existence and distinctness of the SM community type, the GS NatureServe community description should be revised. The description should include *Eleocharis bifida, Schoenolirion croceum, Juncus filipendulus, Carex crawei*, *Allium* sp. nov., *Clinopodium glabellum/arkansanum, Gratiola quartermaniae, Nothoscordum bivalve and Isoetes butleri* as dominant and characteristic taxa. *Hypoxis hirsuta* should be removed from the list of characteristic taxa. Seasonal seepage and overflow from adjacent ephemeral streams should both be included as water sources for this community.

Similar Communities

Several rock outcrop communities occur in eastern North America. Granite outcrops occur in the Piedmont region of Georgia, North Carolina and Alabama (Houle 1987); sandstone glades occur in the Ozark region of Missouri and Arkansas as well as on the Cumberland Plateau (Perkins 1981, Jeffries 1985); dolomitic prairies occur in Illinois (Hill 2003); and alvars occur in the Great Lakes Region (Catling and Brownell 1999. Several of these outcrops harbor communities similar to seasonally wet cedar glades. Granite outcrops of the Georgia Piedmont have cracks and depressions that hold water (Harper 1934). Similar to cedar glades, granitic outcrops have alternating periods of saturation and drought, with seasonal flooding in the spring (McVaugh 1943). Alvars of the Great Lakes region exhibit periodic flooding and seasonal saturation due to seepage (Catling & Brownell 1999). Vernal pools in dolomitic prairies are often seasonally wet (Hill 2003). These seasonally wet communities also share many of the same characteristic plant taxa. *Schoenolirion croceum*, a dominant in seasonally wet cedar glades, also occurs in seasonally wet depressions on granite outcrops (Houle 1987) and seasonally wet areas in sandstone glades (Perkins 1981). *Clinopodium arkansanum, Carex crawei, Gratiola quartermaniae, Scutellaria parvula,* and *Sporobolus vaginiflorus* are characteristic of seasonally wet cedar glades as well alvars and dolomite prairies (Catling and Brownell 1999, Hill 2003). *Isoetes butleri* is also characteristic of both seasonally wet cedar glades and dolomite prairies (Hill 2003). Though seasonally wet cedar glades are similar to other rock outcrop communities in structure, hydrology and some vegetation, they are still quite distinct. Cedar glades occur over limestone unlike granite outcrops and sandstone glades. The dolomite infused rock of dolomitic prairies makes these communities unique. The alvars of the Great Lakes region lack the high number of endemic taxa found in the cedar glades. Though these communities share several similarities with seasonally wet cedar glades, they differ in physical structure, substrate material and total flora, making seasonally wet cedar glades unique.

Wetland Determination

The U.S. Army Corps of Engineers Wetland Delineation Manual (1987) defines wetlands as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Wetlands are defined and categorized according to vegetation, soil, and hydrology. The DRAFT Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Eastern Mountains and Piedmont Region (DWDM) (2008), requires the presence of a minimum of one positive wetland indicator from each parameter (hydrology, soil, and vegetation) in order to be considered a wetland (Table 4.5).

Factor	*Wetland Indicators*
Soil	A1: Histosol
	A2: Histic Epipedon
	A3: Black Histic
	A4: Hydrogen Sulfide
	A5: Stratified Layers
	A6: Organic Bodies
	A7: 5 cm Mucky Mineral
	A9: 1 cm Muck
	A10: 2 cm Muck
	A11: Depleted Below Dark Surface
	A12: Thick Dark Surface
Hydrology	A1: Surface Water
	A2: High Water Table
	A3: Saturation
	B1: Water Marks
	B2: Sediment Deposits
	B3: Drift Deposits
	B4: Algal Mat or Crust
	B5: Iron Deposits
	B7: Inundation Visible on Aerial Imagery
	B9: Water-Stained Leaves
	B13: Aquatic Fauna
	B15: Marl Deposits
	C1: Hydrogen Sulfide Odor
	C3: Oxidized Rhizospheres Along Living Roots
	C4: Presence of Reduced Iron
	C6: Recent Iron Reduction in Tilled Soils
	C7: Thin Muck Surface
Vegetation	1: Rapid Test for Hydrophytic Vegetation
	2: Dominance Test
	3: Prevalence Test
	4: Morphological Adaptations

Table 4.5- Wetland indicators according to DRAFT Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Eastern Mountains and Piedmont Region (DWDM) (2008). For typical wetland systems at least one indicator from all three parameters is required for wetland status unless only obligates populate the floristic community. Hydrology Indicators listed are primary indicators. If no primary indicator is present two or more secondary indicators must be present. Vegetation indicators are tests to determine the presence of hydrophytic vegetation based on wetland codes for the assemblage of plants at the site. The indicators are based on the entire plant community instead of the presence of indicator species.

Vegetation Indicators

Hydrophytic vegetation is macrophytic vegetation that grows in areas with soil sufficiently saturated both in frequency and duration to exert a controlling influence on the plant life present. This vegetation is usually suited to survive in saturated soils due to morphological, physiological or reproductive adaptations. Species that commonly occur in wetlands are assigned an indicator status representative of their ability to survive in saturated soils. The status of OBL, FACW, or FAC (Table 4.6) indicates they are considered to be adapted for life in saturated soil (USACE 1987). Tests to determine the presence of hydrophytic vegetation are based on wetland codes for the assemblage of plants at the site. Indicators are based on the entire plant community instead of the presence of indicator species.

Table 4.6 - Plant wetland indicator status categories according to the USDA (Reed 1997).

Indicator Code	Wetland Type	Comment
OBL	Obligate Wetland	Occurs almost always (estimated probability 99%) under natural conditions in wetlands.
FACW	Facultative Wetland	Usually occurs in wetlands (estimated probability 67%-99%), but occasionally found in non-wetlands.
FAC	Facultative	Equally likely to occur in wetlands or non-wetlands (estimated probability 34%-66%).
FACU	Facultative Upland	Usually occurs in non-wetlands (estimated probability 67%-99%), but occasionally found on wetlands (estimated probability 1%-33%).
UPL	Obligate Upland	Occurs in wetlands in another region, but occurs almost always (estimated probability 99%) under natural conditions in non-wetlands in the regions specified. If a species does not occur in wetlands in any region, it is not on the National List.
NA	No agreement	The regional panel was not able to reach a unanimous decision on this species.
NI	No indicator	Insufficient information was available to determine an indicator status.
NO	No occurrence	The species does not occur in that region.

Soil Indicators

The presence of hydric soils is necessary for wetland status. Hydric soil is soil that is saturated for a sufficient length of time during the growing season to develop anaerobic conditions. Anaerobic soil conditions for a sufficient duration leads to a reducing environment in the soil, lowering the soil redox potential resulting in the reduction of soil components (e.g. iron and manganese oxides) that affect soil color and other physical characteristics. Thus certain soil chromas, notably gray, are indicative of hydric soils (USACE 1987). Hydric soils are also often organic in nature.

Hydrology Indicators

The final criterion for wetland status is hydrology. In areas with wetland hydrology, water has an overriding influence on vegetation and soil due to the development of anaerobic and reducing soil conditions resulting from saturation. According to The U.S. Army Corps of Engineers Wetland Delineation Manual (1987) saturation must occur for 12.5 percent of the growing season, in consecutive days, to fulfill the hydrology requirement. This equates to 25 consecutive days in Davidson County, Tennessee and 24 days in Simpson County, Kentucky (NOAA 2010). The DWDW (2008), includes additional indicators that do not require constant monitoring. These include evidence that the site is used by aquatic fauna, drift deposits, presence of an algal mat or crust, water-stained leaves and the presence of surface water (Table 4.6).

Wetland Assessment of the GS Community

Wetland delineation within seasonal communities is often very complicated. The DWDM identifies seasonal wetlands as problematic wetlands. Problematic wetlands are any wetlands that lack soil, hydrology or vegetation indicators due to disturbance or natural processes (USACE 2008). Water is a powerful force within a community and the presence of this force year-round exerts an unmistakable and unarguable influence over the nature of the entire community. When this force is absent for a large portion of the growing season, its influence is not as obvious. In a system like the cedar glade complex, this influence may be even less obvious. The thin, rocky soil and open habitat are conducive to producing drought like conditions in summer. Is the presence of water in winter and early spring enough of a force to affect the community as a whole? In other words, does the GS community meet the requirements to be classified as a seasonal wetland? To answer this question one must address three factors: hydrology, soil and vegetation.

The hydrological regime of a potential wetland site is important when wetland decisions are being made. Monitoring the hydrology continuously at multiple sites is difficult and expensive and was not possible in this study. However, photographs of each site were taken upon each visit (Appendix C). These photographs clearly show the presence of water during the spring months. The presence of water or saturated soil during the spring combined with the occurrence of aquatic fauna, algal mats, drift deposits and other hydrological indicators at several sites suggest most sites would satisfy one of the hydrology indicators necessary for wetland determination.

Soil assessment for wetland determinations typically consists of sampling and identifying strata within the soil. With a mean soil depth for GS/SM habitats in this study of 7.95 cm, this assessment is difficult. The DWDM (2008) identifies several situations with problematic hydric soils. Seasonally ponded soils with restrictive layers near the surface are one of these problematic situations. The limited saturation depth of these soils may prevent development of typical hydric soil indicators. The presence of restrictive limestone bedrock near the surface within these communities indicates soils in this situation satisfy the requirement for problematic hydric soils. Once categorized as problematic, the relatively level terrain, groundwater seepage, and evidence of seasonal saturation is enough evidence to satisfy the soil requirements for these problematic soils.

The difficulty in monitoring hydrology continuously year round at multiple locations makes the hydrological regime of the community difficult to assess. The science of wetland soils is very well understood, but when soil depths average less than 8 cm. the accepted criteria are not applicable. Even though hydrology and soils are difficult to assess in this situation, presumably both factors influence the vegetation present at the site. A thorough assessment of the vegetation at GS sites would be the most reliable means of assessing the community for wetland status. If water exerts a controlling influence over the community, the vegetation present would exemplify this.

An assessment of the vegetation at a potential wetland site would begin with a list of taxa present and their relative abundance within the site. All species present would then be assigned a wetland code based on Reed (1997). The 159 taxa documented during this study were assigned their appropriate wetland code with 61 or 38.4 percent, having a wetland code of FAC, FACW or OBL (Table 4.7). Analysis of only the 101 taxa which occur in the seasonally wet habitats changes these values slightly, with 40.6 percent of taxa with a wetland code indicating hydrophytic vegetation. If this analysis is limited to taxa which were found exclusively in the GS/SM habitat and no other habitat type, 57.1 percent are hydrophytic.

Table 4.7 - Frequency of wetland codes documented in seasonally wet limestone cedar glades (Reed 1997).

Wetland Code	Frequency in Total Flora	Frequency in GS/SM Flora	Frequency of Taxa Found Exclusively in GS/SM Flora
OBL	8	8	4
FACW	14	11	3
FAC	39	22	5
FACU	37	22	4
UPL	9	5	2
NI	52	33	3
Total	**159**	**101**	**21**

Vegetation indicators are based upon the plant community present, not the presence of indicator species (USACE 2008). Indicator 1, the rapid test for hydrophytic vegetation (Table 4.5), requires that all dominant species across all strata have a wetland code of FACW or OBL. This assessment is based on visual observations in the field. If this indicator is met, no other analysis of vegetation indicators is necessary to satisfy the vegetation requirement. If this indicator is not met, one should proceed to the dominance test, indicator 2 (Table 4.5).

The dominance test requires that greater than 50 percent of all dominant taxa across all strata have a wetland code of OBL, FACW or FAC. Determination of dominant taxa uses the 50/20 rule (USACE 2008). The most dominant taxa which collectively account for 50 percent or more of the total cover area, and any individual taxon that accounts for 20 percent or more of the total area are listed as dominants. For the dominance test, all dominant taxa are ranked equally and at least half of the dominants must have a code of FAC, FACW or OBL. If this is the case, the vegetation indicator is satisfied and no additional vegetation indicators need be assessed.

If indicator 2 is not met, one can proceed to indicator 3, the prevalence index (USACE 2008). This indicator takes cover values into consideration when calculating the prevalence index (PI).

$$PI = \frac{A_{OBL} + 2\,A_{FACW} + 3\,A_{FAC} + 4\,A_{FACU} + 5\,A_{UPL}}{A_{OBL} + A_{FACW} + A_{FAC} + A_{FACU} + A_{UPL}}$$

$AOBL$ = Summed percent cover values of OBL taxa;
$AFACW$ = Summed percent cover values of FACW taxa;
$AFAC$ = Summed percent cover values of FAC taxa;
$AFACU$ = Summed percent cover values of FACU taxa;
$AUPL$ = Summed percent cover values of UPL taxa

A PI of 3 or less (range 1-5) indicates the vegetation is hydrophytic. The final vegetation indicator, morphological adaptations, can be applied if no other indicator is met. This indicator allows the wetland code of a taxon to be adjusted to FAC for the purposes of analysis if there is evidence of morphological adaptations to saturated conditions. Such examples may include "adventitious roots, hypertrophied lenticels, multi-stemmed trunks, and shallow root systems developed on or near the soil surface" (USACE 2008). Once codes have been adjusted, indicator 2 or 3 must be satisfied using the new code to satisfy the vegetation requirement.

Branch 4 of the spring cluster analysis appears to coincide with the GS habitat type classified by NatureServe (2009), but does this habitat type meet the necessary requirements to be classified as a wetland? The GS community type is characterized by the dominant vegetation present. Three of the seven taxa listed in the description have a wetland code of OBL (Table 4.8) (NatureServe 2009). Three additional spring dominants have a code of FAC or FACW. *Allium* sp. nov. and *Eleocharis bifida* both lack a designated wetland code.

The lack of a designated code for *Eleocharis bifida* is a problem if vegetation indicators are to be applied to this community. This taxon is a dominant and characteristic taxon within the community. *Eleocharis bifida* is currently without a code due to two factors, including the limited range of this taxon, and the recentness of its recognition as a distinct taxon. *Eleocharis bifida* was not recognized as a distinct species in 1997 when the current wetland code list was released (Reed 1997). At that time this taxon was still included under *E. compressa*. *Eleocharis compressa* has a wetland code of FACW. Since this code was likely assigned due to *E. bifida* populations, designation of this code to *E. bifida* as well would make sense. Personal observations in the field however suggest that this taxon deserves a code of OBL instead. *Eleocharis bifida* is restricted to cedar glades, and is only found growing in water within these seasonally wet communities (D. Estes pers. communication, K. Norton pers. obs.). This restriction to wet areas throughout its range suggests *E. bifida* should have a wetland code of OBL. This wetland code designation of OBL will be used for *E. bifida* for all subsequent analyses. *Allium* sp. nov. is another taxon lacking a wetland code. Additional work on this taxon is needed before a wetland code can be assigned. The abundance of this taxon in seasonally wet glades however, suggests a code of FAC or FACW should be applied. Two additional species, *Leavenworthia torulosa* (FACU) and *Juncus filipendulus* (FAC), appear to have wetland codes not representative of their true hydrological affinities. *Leavenworthia torulosa* is typically found in shallow depressions over rock where water has accumulated. A code of FACU does not reflect this. *Juncus filipendulus* is restricted to seasonally wet areas in cedar glades and should be given a code that reflects this (D. Estes pers. comm.).

Vegetation indicator 2, the dominance test, was performed using the percent cover values of each quadrat nested within branch 4 (Appendix D). Of the 59 taxa within the branch, 36 satisfied indicator 2. Indicator 3 was then applied to the 13 quadrats that did not satisfy indicator 2. Two of these quadrats satisfied this indicator. In total, 48 of 59 quadrats (81.4 percent) in branch 4 satisfy the vegetation requirement (Figure 4.3). This high percentage suggests the GS habitat type may satisfy the vegetation requirement.

Table 4.8 - Dominant and characteristic taxa of the GS NatureServe community (2009) with their corresponding USDA wetland codes assigned (Reed 1997). *Eleocharis bifida* currently has no designated wetland code, though a code of OBL is suggested and will be used for all subsequent analyses.

Dominant Species	Wetland Code
Eleocharis bifida	NI (*OBL*)
Schoenolirion croceum	OBL
Carex crawei	OBL
Allium sp. nov.	NI
Nothoscordum Bivalve	FAC
Isoetes butleri	OBL
Hypoxis hirsuta	FACW
Juncus filipendulus	FAC

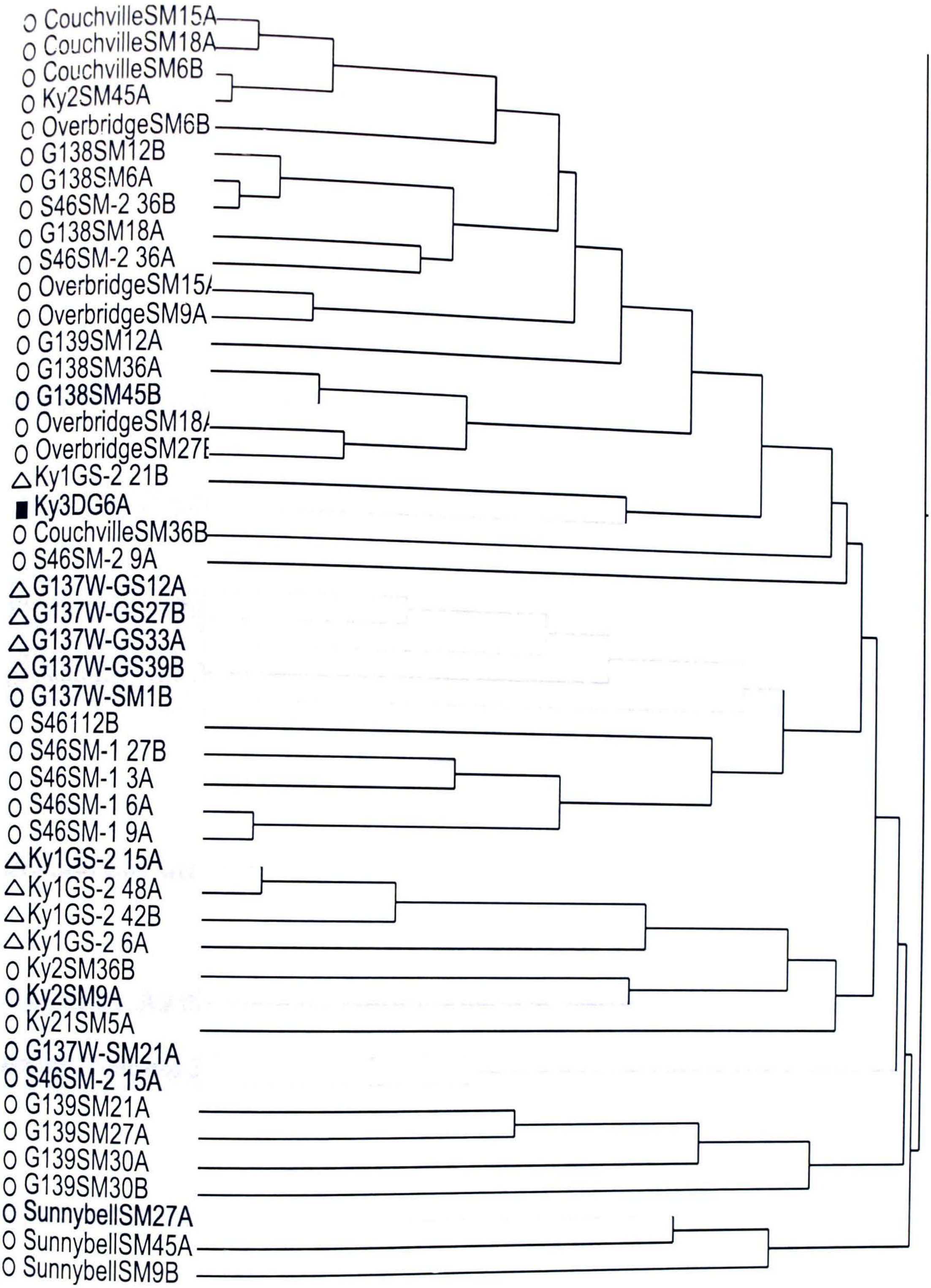


Figure 4.3 - **Branch 4 of the cluster analysis from spring vegetation data. Quadrats highlighted do not meet any of the vegetation indicators. 48 of the 59 total quadrats in branch 4 satisfy either vegetation indicator 2 or 3, resulting in 81.4 percent of the quadrats in branch 4 satisfying the vegetation requirement for wetland delineation.**

The presence of hydrophytic vegetation was shown to occur in a majority of quadrats belonging to the GS community (Appendix D). Therefore the vegetation indicator for this community has been satisfied. Satisfaction of the hydrology and soil indicators were also demonstrated for this community. Satisfaction of all three indicators suggests the GS community type characterized by NatureServe and revised here (p 67), qualifies as a seasonal wetland community according to the USACE wetland delineation protocols (2008). Designation of this community type as a wetland is informative and very useful, but wetland determinations are typically made on a site by site basis. If mean percent cover values for each transect are determined and the vegetation indicators applied to these data, all but one seasonally wet site satisfy the vegetation indicator (Appendix E). Site G137 does not satisfy the vegetation indicator. This site lacks several of the characteristic taxa of the GS community, including *Schoenolirion croceum, Eleocharis bifida* and *Juncus filipendulus*. *Allium* sp. nov. is dominant throughout much of the seasonally wet community at G137. If this taxon were given a wetland code of FAC, FACW or OBL, this site would also satisfy the vegetation requirements for wetland determination. All the remaining seasonally wet sites included in this study satisfy vegetation indicator 2 (Fig. 4.4).

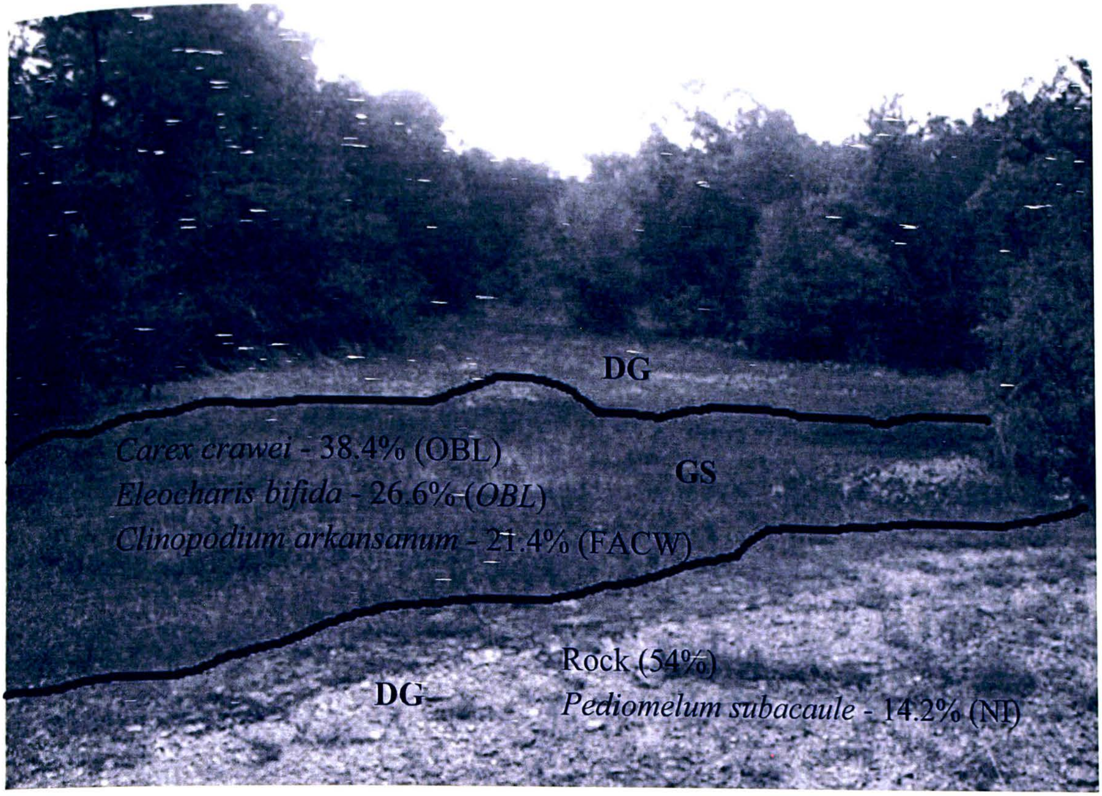


Figure 4.4 - Boundary of GS community at G139 with dominant vegetation in each habitat indicated. Dominant vegetation within the seasonally wet community consisted of taxa with OBL or FACW codes, satisfying the vegetation indicator for wetland determination.

Difficulties in Wetland Determinations

Seasonal wetland determination is a problematic process. Seasonal wetlands are highly responsive to precipitation patterns. An abnormally wet year could increase the amount of water present in a system. An abnormally dry year could do just the opposite, limiting the amount of water present in the system. Thus the vegetation present within these seasonal communities will vary in response to abnormal precipitation levels, particularly annual species that may not be able to take hold in abnormally dry conditions.

During the course of this study, September 2009, May 2009 and May 2010 each had above average rainfall for the Nashville, TN area (Fig.1.2) (NOAA 2010). Notably, May 2010 had a record amount of rainfall resulting in severe flooding in the area. This large amount of rainfall would result in a large amount of water in the system and an excess of water moving across the surface of the glade. This record amount of water movement could displace soil and disrupt vegetation. Ideally the vegetation present in spring 2010 should be compared to that present in a normal year. Unfortunately the above average rainfall in May 2009 does not allow for this comparison. Impacts to the vegetation due to this record rainfall are thus unpredictable. Future monitoring of the sites would be necessary to evaluate the effects.

Another complication in seasonal wetland determinations is the seasonal nature of the hydrology. In a normal year, these systems would be dry by late spring. If field work were not completed prior to this drying out, these communities could be overlooked. As was seen with the summer vegetation, there is no obvious difference between the flora of the DG and GS communities at this time, with the exception of the presence of *Allium* sp. nov. and old culms of *Eleocharis bifida*. Additionally, the summer flora suggests these communities are dry, upland environments. The abundance of grass species, euphorbs, and cactus that are specially adapted to dryer environments does not suggest a site may be a wetland. An abundance of *Allium* sp. nov. at a site during the summer is a good indicator that the site was saturated during the spring, but this species is not restricted to the GS community and would not be reliable as the sole means of identifying the community. Preliminary judgments of a potential seasonally wet cedar glade may be made in the summer and fall, but the site should be revisited in winter or spring for verification.

Conservation

The GS community type is currently given a conservation status rank of G2, or globally imperiled. The Kentucky Glade Seep community however is not ranked. While several quadrats from Flatrock Nature Preserve in Kentucky grouped separate from branch 4 of the spring cluster analysis, eight quadrats were included within branch 4. The similarity in vegetation within these quadrats and the remaining quadrats of branch 4 suggest there is no distinction between seasonally wet communities in Kentucky and Tennessee. Additionally, NatureServe uses the absence of *Schoenolirion croceum* from Kentucky sites as one of the means of distinguishing the Kentucky Glade Seep and Limestone Seep Glade of Tennessee (NatureServe 2009). *Schoenolirion croceum* is not present at all sites in Tennessee either and should not be used as a means of separating the two communities. Thus the Kentucky Glade Seep and Limestone Glade Streamside Meadow communities should be merged and the conservation rank of the community should reflect this merger.

According to NatureServe (2009), a G2 ranking is assigned to indicate a community is "at high risk of extinction or elimination due to very restricted range, very few populations, steep declines, or other factors." This assessment of the community appears to be accurate. The GS community is limited in range to within the cedar glade complex, which is itself limited primarily to the Central Basin and Highland Rim. The sites chosen for this study represent the best of this community type. The Tennessee

Department of Environment and Conservation assisted in the selection of sites by indicating all sites on public land that they were aware of that matched the description given to them. Several of the sites they recommended were not this community type or did not meet the requirements set forth in this study. Few other sites from those visited are known to exist on public land. Reconnaissance field work during the site selection process, led to the identification of less than 30 seasonally wet communities, with most of these on public land. All other examples were on private land and in various states of disturbance. Fewer than 30 known occurrences of the community make it very rare, particularly when most sites are less than 1 ha in area. Most sites seen on private land had evidence of disturbance, such as tire marks, cattle disturbance, and debris throughout the site. There was also evidence that several sites had been scraped for gravel. Road construction adjacent to glades and pond construction were also evident on many potential sites. Few of the sites on private land contained rare taxa, suggesting the vegetation at the site was negatively affected by disturbance.

Both the GS community and the Kentucky Glade Seep community are not ranked at the state level. An S-rank would indicate the rarity of the community within the state. The GS community should be given an S-rank of S2 in Tennessee and S1 in Kentucky. The rarity of this community within Kentucky is evident by examining the rarity of the characteristic taxa for the community. *Isoetes butleri,* for instance, is given a rank of S1 within Kentucky. This taxon is an excellent indicator for this community. *Carex crawei* and *Juncus filipendulus,* both dominant within the GS community are ranked as S2S3 and S2? respectively. The indeterminate nature of these rankings indicates the true rarity of these taxa is not known. Few other seasonally wet sites are known from Kentucky, with less than five sites throughout the state (Julian Campbell, pers. comm.). This regional rarity suggests this community be given an S1 ranking within Kentucky.

There are several existing threats to seasonally wet cedar glades. Like all glades, these communities have often been viewed as waste areas and have been used as such. These areas are often used to dump trash, as pasture land for cattle, and as a source for limestone paving stones and gravel. Use of these areas by all terrain vehicles is also very high. The seasonally wet communities are especially vulnerable to this threat. Disturbances such as roads adjacent to or through glades and pond construction threaten to alter the hydrological regime of these communities. Nearby rock quarries could also alter water table levels, severely impacting these communities. Climate change may also have deleterious effects on this community. Increased mean temperatures, particularly during spring months, could lead to the drying out of these communities earlier in the season. This could prevent the wetland taxa within the community from completing their life cycle. Climate change could also affect precipitation levels, having potentially devastating effects on the hydrology of the community. Development of cedar glade lands poses an additional threat to these communities. With the expansion of Nashville and the surrounding areas, more and more glade land is being developed. It is imperative that seasonally wet cedar glade communities be identified and preserved before they are lost completely.

Identification of seasonally wet limestone cedar glade seeps is imperative. The presence of several species serves as a good indicator of this community. *Eleocharis bifida, Schoenolirion croceum, Juncus filipendulus, Carex crawei, Gratiola quartermaniae* and *Isoetes butleri* are good indicators of this community. These taxa were rarely found outside of the seasonally wet community. During summer months, the presence of *Allium* sp. nov., is a moderately good indicator of the community. The presence of *Eleocharis bifida* culms from the spring is also a good indicator of these communities. Additionally, several of these sites occur along ephemeral streams. As the streams pass through the open glade, there is little channelization due to the very thin soil. Evidence of a stream bed is often evident at the edge of the open glade and can be seen clearly in the bordering cedar woodland where soil depth is much greater. The presence of a stream bed through the glade is not an adequate indicator of the community alone, but can be additional support when combined with vegetation indicators.

The rarity of the community combined with the current threats facing all cedar glades makes identification and conservation of these communities imperative. The presence of several rare and endemic taxa serves to make these areas floristically unique. Their continued destruction could threaten the several rare taxa that are found within these communities.

Future Research Needs

Very little is known about the source of water within these communities. It is presumed that the community is fed by seepage and precipitation. Dye tracing studies to determine the water source for these systems as well as the connectivity to ground water would be very beneficial. Additionally, the true hydrological regime of these sites is not known. The presence of standing water is often evident, but it is not clear how constant this water is. Hydrological monitoring of water depth and soil saturation continuously throughout the year would be beneficial in understanding the role of water in this complex community. Additional soil analysis to determine the true effects of saturation on the soil would also be very informative.

Little is known about the use of these communities by aquatic fauna. During the course of this study, several aquatic fauna were observed, including aquatic insects and salamander larvae. However, the extent to which these sites were utilized by aquatic fauna is not known. The diversity of aquatic fauna in these communities is also not known. The large number of rare and endemic plant species in the sites may suggest the presence of rare aquatic fauna as well. Aquatic macroinvertebrate and herpetological sampling of these communities would be beneficial.

While some work has been completed on testing for physiological adaptations to saturated conditions within cedar glade taxa, most taxa within the seasonally wet community in lack this analysis. Testing for the presence of these adaptations in taxa such as *Eleocharis bifida* and *Juncus filipendulus* would be beneficial.

Rapid and accurate identification of additional examples of this community is imperative. The use of aerial photographs and satellite imagery in identification of these areas would be beneficial to this process.

Conclusions

Within the cedar glade complex exists a distinct community type characterized by seasonal saturation and herbaceous vegetation. Seasonal saturation occurs from winter through spring, with the system typically drying out by mid-summer. Water levels within the community are highly dependent on precipitation levels. Below average precipitation in early spring will cause the community to dry out earlier, while above average precipitation will extend the saturation period.

This seasonal component of limestone cedar glades corresponds to the GS habitat type described by NatureServe (2009). Dominant vegetation includes some combination of the following species: *Eleocharis bifida, Schoenolirion croceum, Carex crawei, Isoetes butleri, Juncus filipendulus, Nothoscordum bivalve* and *Hypoxis hirsuta. Allium* sp. nov. , a potential new taxon to science to be split out of *A. cernuum* is often dominant during the summer and fall. This taxon may serve as a good indicator species of this community when the system lacks surface water.

Seasonally wet limestone cedar glades have been neglected in previous descriptions of glade communities. Previous classifications focused primarily on communities present during summer and fall. These seasonal communities seem to be a spring component of communities 6 and 7 as described by Somers (1986), though a thorough characterization of spring glade communities is needed.

Wetland assessment of the GS community suggests it may satisfy requirements for wetland delineation as set forth by the Army Corps of Engineers Wetland Delineation Manual and appropriate regional supplements (1987, USACE 2008). This determination may allow for increased conservation of this rare community. With over half of glade lands and 90 percent of in-tact glades lost to development and agriculture, it is imperative to preserve cedar glade communities now before they are lost forever (Noss et al. 1995).

LITERATURE CITED

Baskin, J.M, Baskin, C.C. 1973. Observations on the ecology of Sporobolus vaginiflorus in cedar glades. Castanea 38:25-35.

Baskin, J.M, Baskin, C.C. 1985. A floristic study of a cedar glade in Blue Licks Battlefield State Park, Kentucky. Castanea. 50(1):19-25.

Baskin, J.M, Baskin, C.C.. 1986. Distribution and geographical/evolutionary relationships of cedar glade endemics in southeastern United States. *ASB Bulletin.* 33(4):138-154.

Baskin, J.M, Baskin, C.C. 1989. Cedar glade endemics in Tennessee, and a review of their autecology. *Journal of the Tennessee Academy of Science.* 64(3):63-74.

Baskin, J.M, Baskin, C.C. 1996. Bessey Picklesimer's little-known quantitative study on the vegetation of a cedar glade in the central basin of Tennessee. *Castanea.* 61(1):25-37.

Baskin, J.M, Baskin, C.C. 1999. Cedar glades of the southeastern United States. Pp. 206-219. In: R. C. Anderson, J. S. Fralish, and J. M. Baskin (eds.), Savannas, Barrens, and rock outcrop plant communities of North America. Cambridge University Press, Cambridge, UK.

Baskin, J.M, Baskin, C.C. 2003. The vascular flora of cedar glades of the southeastern united states and its phytogeographical relationships. *Journal of the Torrey Botanical Society.* 130(2):101-118.

Baskin J.M., Webb D.H., Baskin C.C. 1995. A floristic plant ecology study of the limestone glades of northern Alabama. Bulletin of the Torrey Botanical Club. 122(3):226-242.

Bonham, C.D. 1989. *Measurements for terrestrial vegetation*. John Wiley & Sons, Inc: New York. 100-108.

Bridges E.L., Orzell S.L. 1986. Distribution patterns of the non-endemic flora of middle Tennessee limestone glades. *ASB Bulletin*. 33(4):155-166.

Catling, P.M, Brownell, V.R. 1999. Alvars of the Great Lakes Region. Pp. 375-391. In: R. C. Anderson, J. S. Fralish, and J. M. Baskin (eds.), Savannas, Barrens, and rock outcrop plant communities of North America. Cambridge University Press, Cambridge, UK.

Chester E.W., Wofford, B.E., Estes, D, Bailey, C. 2009. A fifth checklist of Tennessee vascular plants. Botanical Research Institute of Texas: Fort Worth, TX.

Crabtree, T. 2008. "Tennessee Rare Plant List". Tennessee Natural Heritage Program. Division of Natural Areas. Tennessee Department of Environment and Conservation.

Eickmeir W.G. 1986. The distribution of photosynthetic pathways among cedar glade plants. *ASB Bulletin*. 33(4):200-205.

EPA. Environmental Protection Agency. 2009. Wetland Types. http://www.epa.gov/owow/wetlands/.

Estes, D., Small, R.L. 2007. Two new species of *Gratiola* (Plantaginaceae) for eastern North America and an updated circumscription for *Gratiola neglecta*. J. Bot. Res. Inst. Texas 1:149-170.

Estill J.C., Cruzan M.B. 2001. Phytogeography of rare plant species endemic to the southeastern united states. *Castanea*. 66:3-23.

Gattinger, A. 1887. The Tennessee flora with special reference to the flora of Nashville. Published by the author, Nashville, Tenn., and printed by Carlon and Hollenbeck, Indianapolis, Ind.

Gattinger, A. The flora of Tennessee and a philosophy of botany. Press of the Gospel Advocate Publ. Co., Nashville, Tenn.

Harper R.M. 1926. The cedar glades of middle Tennessee. *Ecology*. 7(1):48-54.

Harper, R.M.. 1939. Granite outcrop vegetation in Alabama. *Torreya* 39:153-159.

Hershey, R.E., Maher, S.W. 1985. Limestone and dolomite resources of Tennessee. Tennessee Geol. Surv. Bull. 65. Ed. 2. State of Tennessee, Department of Conservation, Nashville.

Hill, S.R. 2003. Botanical survey of dolomite prairie remnants, natural plant communities, and threatened and endangered plants at the Interstate 55 (FAI 55) – Arsenal Road interchange project, Cjannahon, Will, County, Illinois. Center for Biodiversity Technical Report 2003 (37). Prepared for Bureau of Design and Environment, Illinois Department of Transportation, Springfield by the Illinois Natural History Survey, Campaign, submitted 31 Dec. 2003. 98 pp + maps.

Houle, G. 1987. Vascular plants of Arabia Mountain, Georgia. *Bulletin of the Torrey Botanical Club* 114:412-418.

Jeffries, D.L. 1985. Analysis of the vegetation and soils of glades on calico rock sandstone in northern Arkansas. *Bulletin of the Torrey Botanical Club* 112:70-73.

JMP, Version 8. SAS Institute Inc., Cary, NC, 1989-2008.

Killebrew, J.B. Safford, J.M. 1874. Introduction to the Resources of Tennessee. Travel, Eastman, and Howell, Printers to the State, Nashville, Tenn.

KSNPC. Kentucky State Nature Preserves Commission. 2006. Kentucky State Nature Preserves Commission. "Kentucky Rare Plant Database". http://eppcapp.ky.gov/nprareplants/index.apsx

KSNPC. Kentucky State Nature Preserves Commission. 2010. State nature preserves and state natural areas directory.

KY-EPPC. 2008. Kentucky Exotic Pest Plant Council. http://www.se-eppc.org/ky/lists.htm

Lawless, P.J., Baskin, J.M., Baskin, C.C. 2004. The floristic ecology of xeric limestone prairies in Kentucky, and a comparison to limestone cedar glades and deep-soil barrens. Sida 21:1055-1079.

McVaugh, R. 1943. The vegetation of the granitic flat-rocks of the southeastern United States. *Ecological Monographs* 13:119-166.

Murrell, Z.E., Wofford, B.E. 1987. Floristics and phytogeography of Big Frog Mountain, Polk County, Tennessee. Castanea 52:262-290.

NatureServe. 2009. Ecological Communities and Systems. http://www.NatureServe.org/explorer/

NOAA. National Climatic Data Center. 2010. U.S. Department of Commerce.

Noss, R.F., LaRoe, E.T., Scott, J.M.. 1995. Endangered ecosystems of the United States: a preliminary assessment of loss and degradation. National Biological Survey, Biological Report No. 28. U.S. Department of the Interior, Washington, DC.

Perkins, B.E. 1981. "Vegetation of sandstone outcrops of the Cumberland plateau." MS Thesis. U of Tennessee, 1981.

Quarterman, E. 1947. A preliminary survey of the bryophytes of two cedar glades. The Bryologist 50: 377-380.

Quarterman E. 1950. Ecology of cedar glades I. Distribution of glade flora in Tennessee. *Bulletin of the Torrey Botanical Club.* 77(1):1-9.

Quarterman E. 1950b. Major plant communities of Tennessee cedar glades. *Ecology.* 31(2):234-254.

Quarterman E. 1989. Structure and dynamics of the limestone cedar glade communities in Tennessee. *Journal of the Tennessee Academy of Science.* 64(3):155-158.

Quarterman, E. & M.P. Burbanck & D. J. Shore. 1993. Rock outcrop communities: Limestone, sandstone, and granite. Pp. 35-86 in W. H. Martin, S. G. Boyce & A. C. Echternacht (eds.), Biodiversity of southeastern United States/upland terrestrial communities. John Wiley and Sons, New York.

Reed Jr., P.B. (compiler). 1997. Revision of the National List of Plant Species that Occur in Wetlands. In Cooperation with the National and Regional Interagency Review Panels: U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, and Natural Resources Conservation Service. Department of Interior, U.S. Fish and Wildlife Service, Washington, DC, USA.

Safford, J.M. 1851. The Silurian Basin of Tennessee, with notices of the strata surrounding it. Amer. J. Sci. & Arts, 2nd Ser. 12:352-361 + map.

Somers P. 1986. Preliminary analyses of plant communities and seasonal changes in cedar glades of middle Tennessee. *ASB Bulletin.* 33(4):178-192.

TDEC. Tennessee Department of Environment and Conservation. 2010. Resource Management Division. Natural Heritage Inventory Program. State Natural Areas. http://tn.gov/environment/na/natareas/map.shtml

TN-EPPC. Tennessee Exotic Pest Plant Council. 2009. "TN-EPPC Invasive Exotic Pest Plants in Tennessee." 2 ed. (http://www.tneppc.org/invasive_plants)

USACE. US Army Corps of Engineers. 1987. "Corps of engineers wetlands delineation manual," US Army Corps of Engineers. Technical Report Y-87-l, US Army Engineer Waterways Experiment Station, Vicksburg, MS., U.S.

USACE. US Army Corps of Engineers. 2008. *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Eastern Mountains and Piedmont Region*, ed. J. S. Wakeley, R. W. Lichvar, and C. V. Noble. ERDC/EL TR-0X-XX. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

USDA. United States Department of Agriculture. 2010.National Resources Conservation Service. Web Soil Survey. http://www.websoilsurvey.nrcs.usda.gov

U.S. Fish and Wildlife Service. 2009. Threatened and Endangered Species System. http://www.fws.gov/Endangered/listing/index.html

Ware, S. 2002. Rock outcrop communities (glades) in the Ozarks: A synthesis. Southw. Nat. 47: 585-597.

Wilson, C.W., Jr. 1940. Progress geologic map of middle Tennessee. Tennessee Department of Conservation, Division of Geology. In pocket of Smith, R. W. and G. L. Whitlatch. 1940. The phosphate deposits of Tennessee. Tennessee Dept. Conserv. Div. Geol. Bull. 48.

mbush, D.J., Barrow, M.D., Costin, A.B. 1967. Color stereo-photography for the measurement of vegetation. *Ecology*. 48:150-152.

APPENDICES

APPENDIX A

Checklist of the Vascular Flora of Seasonally Wet Limestone Cedar Glades

CHECKLIST OF THE VASCULAR FLORA OF SEASONALLY WET LIMESTONE CEDAR GLADES

Taxa are arranged according to family within four major groups: Pteridophytes, Gymnosperms, and Angiosperms (Monocots, Dicots). Nomenclature follows Chester et al. (2009). Non-native taxa are indicated by an asterisk (*), taxa endemic to cedar glades by two asterisks (**) and taxa listed as rare at the state or federal level indicated by a plus (†). Site numbers where a taxon was documented are listed behind the common name, followed by all habitats the taxon occurred in in brackets (BV = Border Vegetation, DG = Dry Glade, GS/SM = Limestone Glade Seep or Streamside Meadow Community). Following habitat codes is an abundance statement following Murrell and Wofford (1987) (V=very rare, R=rare, S=scarce, I=infrequent, O=occasional, F=frequent, C=common), followed by designated wetland codes as indicated by Reed (1997). Following wetland codes are biogeographical affinities (INT=intraneous, WEST=western extraneous, EAST=eastern extraneous, NORTH=northern extraneous, SOUTH=southern extraneous, D- =disjunct) followed by the collection number for specimens deposited at APSC. A caret (^) indicates the taxon was observed but not collected.

PTERIDOPHYTES

Aspleniaceae

Asplenium platyneuron (L.) B.S.P (Ebony Spleenwort)—1; {BV}; S; FACU; INT; (00188).

Isoetaceae

†*Isoetes butleri* Engelm. (Limestone Quillwort)—2,7; {**GS/SM**}; I; OBL; WEST; (00504).

Ophioglossaceae

Ophioglossum engelmannii Prantl (Limestone Adders Tongue)—1,6; {BV, **GS/SM**}; R; FACU; WEST; (00435).

Woodsiaceae

Woodsia obtusa (Spreng.) Torr. (Bluntlobe Cliff Fern)—1,4,5; {BV}; I; NI; INT; (00047).

GYMNOPERMS

Cupressaceae

Juniperus virginiana L. (Eastern Red Cedar)—1,2,3,4,5,6,7,8,9,10; {BV}; C; FACU; INT; (00240).

ANGIOSPERMS: MONOCOTS

Agavaceae

Manfreda virginica (L.) Rose (False Aloe)—2,4,6,7; {DG, **GS/SM**}; S; NI; INT; (00527).

†*Schoenolirion croceum* (Michx.) Wood (Yellow Sunnybell)—5,6,9,10; {BV, DG, **GS/SM**}; F; OBL; SOUTH; (00399).

Alliaceae

Allium canadense L. (Meadow Garlic)—3,4,10; {DG, **GS/SM**}; S; FACU; INT; (00471).

*******Allium* sp. nov.— 4,5,6,7,8,10; {DG, **GS/SM**}; C; NI; INT; (00045).

Nothoscordum bivalve (L.) Britt. (False Garlic)—3,4,6,7,8,9; {DG, **GS/SM**}; C; FAC; INT; (00221).

Amaryllidaceae

Hypoxis hirsuta (L.) Coville (Star-Grass)—1; {BV, **GS/SM**}; S; FAC; INT; (00341).

Commelinaceae

**Commelina communis* L. (Asiatic Dayflower)—3; {DG}; R; FAC; (00219).

Cyperaceae

†*Carex crawei* Dewey (Crawe's Sedge)—1,2,4,5,6,7,9,10; {BV, DG, **GS/SM**}; F; OBL; WEST; (00414).

Carex glaucodea Tuckerman ex. Olney (Blue Sedge)—1,3; {DG, **GS/SM**}; UR; FAC; INT; (00419).

Carex granularis Muhl. ex Willd. (Limestone Meadow Sedge)—4,5; {DG, **GS/SM**}; S; FACW; NORTH; (00410).

Carex hirsutella Mackenzie (Fuzzy Sedge)—3,6,8; {**GS/SM**}; S; FAC; NORTH; (00428).

Cyperus acuminatus Torr. & Hook. (Taperitip Flat Sedge)—1; {**GS/SM**}; R; OBL; WEST; (00490).

Cyperus squarrosus L. (Bearded Flat Sedge)—2,3,5,9; {DG, **GS/SM**}; O; OBL; INT; (00116).

***Eleocharis bifida* S.G. Smith (Glade Spike Rush)—1,2,4,5,6,7,8,10; {**GS/SM**}; C; NI-*OBL*; INT; (00397).

Scirpus pendulus Muhl. (Rufous Bulrush)—1,2,3,10; {**GS/SM**}; I; OBL; NORTH; (00473).

Dioscoreaceae

Dioscorea villosa L. (Wild Yam)—9; {BV}; S; FACW; INT; (00517).

Iridaceae

Sisyrinchium albidum Raf. (White Blue-eyed Grass)—4,5,6,7,8,9; {BV, DG}; F; FACU; INT; (00003).

**Iris domestica* (Blackberry Lilly)— 4,6,7; {BV}; R; UPL; (^).

Juncaceae

Juncus brachycarpus Engelm. (Whiteroot Rush)—2; {**GS/SM**}; R; FAC; INT; (00502).

†*Juncus filipendulus* Buckl. (Ringseed Rush)—1,2,4,5,6,8,9,10; {**GS/SM**}; C; FAC; D-WEST; (00031).

Orchidaceae

Liparis liliifolia (L.) Rich. ex Lindl (Lilyleaved Tway Blade)—1; {BV, **GS/SM**}; UR; FACU; NORTH; (00185).

Spiranthes cernua (L.) Rich (Nodding Ladies'-Tresses)—1,2,5; {DG, **GS/SM**}; R; FACW; INT; (00189).(Note: These populations closely resemble *S. magnicamporum* and the two should be closely compared*)*

Spiranthes lacera (Raf.) Raf. var. *gracilis* (Bigelow) Luer (Northern Slender Ladies'-Tresses)—1; {BV, **GS/SM**}; UR; FAC; INT; (^).

Poaceae

Andropogon gerardii Vitman. (Big Bluestem)—10; {DG, **GS/SM**}; S; FAC; INT; (00160).

†*Bouteloua curtipendula* (Michx.) Torr. (Sideoats Grama)—7; {DG, **GS/SM**}; S; NI; WEST; (00076).

Bromus commutatus* Schrad. (Meadow Brome)—1; {DG, **GS/SM}; R; NI; (00478).

Chasmanthium latifolium (Michx.) Yates (Indian Woodoats)—10; {DG, **GS/SM**}; R; FAC; INT; (00157).

Danthonia spicata (L.) Beauv. ex Roem. & Schult. (Poverty Oat Grass)—1; {DG, **GS/SM**}; S; NI; NORTH; (00195).

Dichanthelium acuminatum (S.W.) Gould & C.A. Clark (Tapered Rosette Grass)—1,5,6; {DG, **GS/SM**}; I; FAC; INT; (00402).

Dichanthelium laxiflorum (Lam.) Gould (Soft-Tufted Panic Grass)—1; {BV}; S; FAC; SOUTH; (00197).

Dichanthelium malacophyllum (Nash.) Gould (Soft Leaved Panic Grass)—1,5,7; {DG, **GS/SM**}; O; NI; WEST; (^).

Eragrostis frankii C.A.Mey ex Steud (Sandbar Love-Grass)—1,8; {DG, **GS/SM**}; I; FACW; NORTH; (00133).

Leersia virginica Willd. (White Grass)—1; {DG}; R; FACW; INT; (00199).

Melica mutica Walt. (Two Flower Melic Grass)—4,5,6,7,8,9,10; {DG, BV}; C; NI; SOUTH; (00413).

Muhlenbergia schreberi J.F. Gmel. (Nimbleweed)—1; {**GS/SM**}; R; FAC; INT; (00200).

Panicum flexile (Gatt.) Scribn. (Wiry Panic Grass)—1,3,5,7,8,9,10; {BV, DG, **GS/SM**}; C; FAC; INT; (00201).

Panicum gattingeri Nash (Gattinger's Panic Grass)—1,2,3,4,5,9; {DG, **GS/SM**}; C; FAC; NORTH; (00202).

Paspalum setaceum Michx. (Thin Paspalum)—1; {DG, **GS/SM**}; R; FAC; INT; (00203).

Schizachyrium scoparium (Michx.) Nash (Little Bluestem)—1,4,5,7,8,10; {DG}; F; FACU; INT; (00162).

Setaria parviflora (Poir.) Kerguelen (Marsh Bristle Grass)—4,5,8,10; {**GS/SM**}; O; FAC; INT; (00054).

Sporobolus vaginiflorus (Torr. ex A. Gray) Alph. Wood (Poverty Dropseed)—1,2,3,4,5,6,7,8,9,10; {DG}; C; UPL; (00056).

Tridens flavus (L.) Hitchc. (Purpletop Tridens)—1,8; {**GS/SM**}; S; FACU; INT; (00137).

ANGIOSPERMS: DICOTS

Acanthaceae

Ruellia humilis Nutt. (Fringeleaf Wild Petunia)—1,4,5,6,7,8,9,10; {DG, **GS/SM**}; C; FACU; WEST; (00151).

Anacardiaceae

Rhus glabra L. (Smooth Sumac)—4; {BV}; S; NI; INT; (^).

Rhus aromatica Ait. (Fragrant Sumac)—7,10; {BV}; S; NI; WEST; (00512).

Apiaceae

Daucus carota* L. (Queen Anne's Lace)—4,8,9; {DG, **GS/SM}; S; NI; (00097).

Apocynaceae

Apocynum cannabinum L. (Indian Hemp)—10; {BV}; R; FAC; INT; (^).

Asclepiadaceae

Asclepias verticillata L. (Whorled Milkweed)—4,5,10; {DG, **GS/SM**}; I; NI; INT; (00508).

Asclepias viridiflora Raf. (Green Comet Milkweed)—6,8; {BV, DG}; S; NI; WEST; (00129).

Asclepias viridis Walt. (Green Antelopehorn)—6; {DG}; UR; NI; WEST; (00433).

Asteraceae

Ageratina altissima (L.) R.M. King & H. Rob. (White Snakeroot)—1,4,7,8,10; {DG, **GS/SM**}; O; FACU; INT; (00192).

Ambrosia artemisiifolia L. (Annual Ragweed)—1,3,4,5,7,8,9,10; {DG, **GS/SM**}; F; FACU; INT; (00246).

Bidens bipinnata L. (Spanish Needles)—1; {BV}; R; NI; INT; (00182).

Cirsium discolor (Muhl. ex Willd.) Spreng. (Field Thistle)—2,4,7,8; {BV}; S; UPL; NORTH; (^).

Conoclinium coelestinum (L.) DC. (Blue Mistflower)—1,2; {BV}; S; FAC; INT; (00208).

**†*Echinacea tennesseensis* (Beadle) Small (Tennessee Purple Coneflower)—4,8; {DG}; R; NI; INT; (^).

Erechtites hieraciifolia (L.) Raf. ex DC. (American Burnweed)—1; {BV}; UR; FAC; INT; (00170).

Erigeron strigosus Muhl. ex Willd. var. *calcicola* J.Allison (Limestone Fleabane)—1,3,4,5,7,8,9,10; {DG, **GS/SM**}; C; FAC; INT; (00256).

Eupatorium serotinum Michx. (Lateflowering Thoroughwort)—1; {BV, DG, **GS/SM**}; R; FAC; INT; (00194).

Grindelia lanceolata Nutt. (Narrowleaf Gum Weed)—4,10; {DG, **GS/SM**}; S; NI; WEST; (00241).

Helenium autumnale L. (Common Sneezeweed)—4; {DG, **GS/SM**}; R; FACW; INT; (00228).

Helianthus hirsutus Raf. (Hairy Sunflower)—1; {DG}; R; FAC; INT; (00169).

Leucanthemum vulgare* Lam. (Oxeye Daisy)—1,3,4,5,8,10; {BV, DG, **GS/SM}; F; UPL; (00416).

Packera anonyma (Wood) Weber & A.Löve (Small's Ragwort)—1,4,5,6,7,8,10; {DG, **GS/SM**}; C; FACU; INT; (00430).

Polymnia canadensis L. (Whiteflower Leafcup)—5,7,9; {BV}; S; NI; NORTH; (00516).

Ratibida pinnata (Vent.) Barnhart (Pinnate Prairie Coneflower)—10; {**GS/SM**}; UR; NI; WEST; (00475).

Rudbeckia triloba L. (Brown Eyed Susan)—4,5,6,7,8,9,10; {DG}; F; FACU; INT; (00412).

†*Symphyotricum priceae* (Britt.) Nesom (Lavender Old Field Aster)—1,4,10; {DG, **GS/SM}; S; NI; INT; (00088).

Verbesina virginica L. (White Crownbeard)—9; {BV, DG, **GS/SM**}; R; FACU; SOUTH; (^).

Balsaminaceae

Impatiens capensis Meerb. (Jewelweed)—10; {**GS/SM**};UR; FACW; INT; (00146).

Boraginaceae

Heliotropium tenellum (Nutt.) Torr. (Pasture Heliotrope)—4,5,7,8,9,10; {DG, **GS/SM**}; C; NI; WEST; (00155).

Brassicaceae

**Cardamine hirsuta* L. (Hairy Bitter Cress)—9; {DG}; R; FAC; (00263).

***Leavenworthia stylosa* Gray (Cedar Glade Cress)—4,5,7,8,9; {DG, **GS/SM**}; O; NI; INT; (00264).

†*Leavenworthia torulosa* Gray (Necklace Glade Cress)—1; {DG, **GS/SM}; R; FACU; INT; (^).

***Leavenworthia uniflora* (Michx.) Britt. (Michaux's Glade Cress)—2,3,8; {DG}; S; FAC; INT; (^).

Cactaceae

Opuntia humifusa (Raf.) Raf. (Prickly Pear)—3,4,6,9; {DG}; O; NI; INT; (^).

Campanulaceae

†*Lobelia appendiculata* A. DC. var. *gattingeri* (A. Gray) McVaugh (Gattinger's Lobelia)—1,4,5,6,7,8,9,10; {DG, **GS/SM}; C; FAC; INT; (00037).

Triodanis perfoliata (L.) Nieuwl. var. *perfoliata* (Clasping Venus' Looking Glass)—1,4; {DG, **GS/SM**}; S; FACU; INT; (00479).

Caryophyllaceae

Minuartia patula Michx. (Pitcher's Sandwort)—4,5,6,7,8,9; {DG, **GS/SM**}; F; FAC; WEST; (00010).

Clusiaceae

***Hypericum dolabriforme* Vent. (Straggling St. Johnswort)—1,2; {DG, **GS/SM**}; R; NI; INT; (00176).

Hypericum gentianoides (L.) B.S.P (Orangegrass)—2; {**GS/SM**}; UR; FACU; INT; (00210).

Hypericum sphaerocarpum Michx. (Roundseed St. Johnswort)—1,2,3,4,5,6,7,8,9,10; {DG, **GS/SM**}; C; FACU; WEST; (00060).

Convolvulaceae

Ipomoea pandurata (L.) G. Mey. (Man of the Earth)—4; {DG}; R; FACU; INT; (^).

Crassulaceae

Sedum pulchellum Michx. (Widowscross)—1,4,5,7,8,9; {DG, **GS/SM**}; F; UPL; D-WEST; (00406).

Cucurbitaceae

Melothria pendula L. (Guadeloupe Cucumber)—1; {BV}; R; FACW; SOUTH; (^).

Ebenaceae

Diospyros virginiana L. (Persimmon)—6,10; {BV, **GS/SM**}; S; FACU; INT; (^).

Euphorbiaceae

Acalypha gracilens A.Gray (Slender Three Seed Mercury)—1,7; {DG, **GS/SM**}; S; NI; INT; (00069).

Acalypha virginica L. (Virginia Three Seed Mercury)—1; {DG}; R; FACU; INT; (00175).

Chamaesyce maculata (L.) Small (Spotted Sandmat)—3; {DG, **GS/SM**}; R; FACU; INT; (^).

Chamaesyce nutans (Lag.) Small (Eyebane)—5,7,8,10; {DG, **GS/SM**}; O; FACU; INT; (00074).

Chamaesyce prostrata* (Ait.) Small (Prostrate Sandmat)—1,8,9; {DG, **GS/SM}; S; FAC; (^).

Croton capitatus Michx. (Hogwort)—1,2,3,4,5,7,8,9,10; {DG, **GS/SM**}; C; NI; WEST; (00166).

Croton monanthogynus Michx. (Prairie Tea)—1,2,3,4,5,6,7,8,9; {DG, **GS/SM**}; C; NI; WEST; (00247).

Euphorbia dentata Michx. (Toothed Spurge)—1,3,5,8,9; {DG, **GS/SM**}; F; NI; WEST; (00518).

Euphorbia spathulata Lam. (Warty Spurge)—4; {DG}; R; FAC; WEST; (^).

Fabaceae

Cercis canadensis L. (Eastern Redbud)—5,10; {DG}; S; FACU; INT; (00509).

Chamaecrista fasciculata (Michx.) Greene (Partridge Pea)—6,8,10; {BV, DG}; I; FACU; INT; (00120).

†*Dalea foliosa* (Gray) Barneby (Leafy Prairie Clover)—5; {DG, **GS/SM}; UR; NI; INT; (^).

***Dalea gattingeri* (A. Heller) Barneby (Purpletassels)—2,3,4,5,6,7,8,9,10; {BV}; UR; NI; INT; (00398).

Desmanthus illinoensis (Michx.) MacMill. ex B.L. Rob. & Fern. (Prairie Bundle Flower)—4,10; {DG, **GS/SM**}; S; FAC; WEST; (00090).

Lespedeza cuneata* (Dum. Cours.) G. Don (Chinese Lespedeza)—5,10; {GS/SM**}; S; UPL; (00141).

***Pediomelum subacaule* (Torr. & Gray) Rydb. (Indian Breadroot)—4,6,7,8,9,10; {DG, **GS/SM**}; C; NI; INT; (00346).

Stylosanthes biflora (L.) B.S.P (Sidebeak Pencil Flower)—2; {DG}; R; NI; INT; (00501).

**Trifolium campestre* Schreb. (Field Clover)—2,4,7,10; {BV}; O; NI; (00033).

Gentianaceae

Sabatia angularis (L.) Pursh (Rose Pink)—5,10; {**DV, DG**}; S; FAC; INT; (00505).

Lamiaceae

Blephilia ciliata (L.) Benth (Downy Pagoda Plant)—4; {DG, **GS/SM**};R; NI; INT; (00455).

Clinopodium arkansanum (Nutt.) House (Limestone Calamint)—6,7,9,10; {DG, **GS/SM**}; O; FACW; D-WEST; (00472).

Clinopodium glabellum (Michx.) Kuntze (Ozark Calamint)—4,5,8,9; {DG, **GS/SM**}; O; FACW; INT; (00083).

Isanthus brachiatus (L.) B.S.P (Fluxweed)—1,4,7,10; {DG, **GS/SM**}; O; NI; NORTH; (00177).

Salvia lyrata L. (Lyreleaf Sage)—7; {BV}; R; FAC; INT; (00420).

Scutellaria parvula Michx. (Small Scullcap)—1,2,3,4,5,6,7,8,9; {BV}; C; FACU; INT; (00009).

Loganiaceae

Mitreola petioloata (J.F. Gmel.) Torr. & Gray (Lax Hornpod)—10; {**GS/SM**}; R; FACW; SOUTH; (00507).

Lythraceae

Cuphea viscosissima Jacq. (Blue Waxweed)—1,3,7,10; {DG, **GS/SM**}; O; FACW; NORTH; (00071).

Lythrum alatum Pursh (Winged Lythrum)—10; {**GS/SM**}; R; FACW; WEST; (^).

Malvaceae

Malvastrum hispidum (Pursh) Hochr. (Hispid False Mallow)—1,3; {DG, **GS/SM**}; S; NI; D-WEST; (00173).

Montiaceae

†*Phemeranthus calcaricus* (S.Ware) Kiger (Limestone Fameflower)—3,4,5,7,9; {DG, **GS/SM}; F; NI; INT; (00101).

Moraceae

Morus rubra L. (Red Mulberry)—1; {BV}; S; FAC; INT; (^).

Oleaceae

†*Forestiera ligustrina* (Michx.) Poir. (Upland Swamp Privet)—1,2,3,4,5,6,7,8,9,10; {BV}; C; FAC; SOUTH; (00213).

Fraxinus americana L. (American Ash)—4,9; {BV}; O; FACU; INT; (00512).

Fraxinus quadrangulata Michx. (Blue Ash)—4; {BV}; S; NI; NORTH; (00528).

**Ligustrum sinense* Lour. (Chinese Privet)—10; {BV}; S; FAC; (00145).

Onagraceae

Gaura longiflora Spach (Longflower Beeblossom)—10; {DG, **GS/SM**}; UR; NI; WEST; (00138).

†*Oenothera macrocarpa* Nutt. (Bigfruit Evening Primrose)—10; {DG, **GS/SM**}; R; NI; D-WEST; (00142).

Oxalidaceae

Oxalis stricta L. (Common Yellow Oxalis)—1; {DG}; I; UPL; INT; (00244).

Oxalis violaceae L. (Violet Wood Sorrel)—6; {BV, DG, **GS/SM**}; I; NI; INT; (^).

Plantaginaceae

Penstemon calycosus Small (Long Sepal Beard Tongue)—10; {BV, DG, **GS/SM**}; R; FACU; NORTH; (00474).

Plantago virginica L. (Virginia Plantain)—1,3,6,7; {DG, **GS/SM**}; O; FACU; INT; (00488).

Polemoniaceae

†*Phlox bifida* Beck. ssp. *stellaria* Wherry (Cleft Phlox)—6; {DG}; I; NI; INT; (00345).

Polygalaceae

Polygala verticillata (Whorled Milkwort)—1,7,10; {BV, DG, **GS/SM**}; I; UPL; INT; (00485).

Portulacaceae

Portulaca oleracea* L. (Little Hogweed)—1; {GS/SM**}; R; FACU; (^).

Primulaceae

Dodecatheon meadia L. (Shooting Star)—1,7,9,10; {BV, DG, **GS/SM**}; O; FACU; WEST; (00421).

Ranunculaceae

Aquilegia canadensis L. (Red Columbine)—6,9; {DG, **GS/SM**}; O; FAC; NORTH; (00437).

**†*Delphinium carolinianum* Walt. ssp. *calciphilum* Warnock (Carolina Larkspur)—4,6,9,10; {BV}; F; NI; INT; (00451).

Rosaceae

Potentilla simplex Michx. (Common Cinquefoil)—5,7,8,9; {BV, DG, **GS/SM**}; F; FACU; INT; (00013).

Rosa carolina L. (Carolina Rose)—8,9; {BV, DG}; I; FACU; INT; (^).

Rubiaceae

Diodia teres Walt. (Poorjoe)—1,2,6,7,8,10; {BV}; F; FACU; INT; (00494).

Galium virgatum Nutt. (Southwestern Bedstraw)—6; {DG, **GS/SM**}; S; NI; D-WEST; (00434).

Hedyotis nigricans (Lam.) Fosberg (Diamond Flowers)—4,6,7,8,10; {DG, **GS/SM**}; F; NI; WEST; (00510).

Houstonia purpurea L. var. *calycosa* A. Gray (Venus' Pride)—1,4,5,6,7,8,9,10; {DG, **GS/SM**}; C; NI; INT; (00012).

Rutaceae

Ptelea trifoliata L. (Common Hoptree)—10; {DG}; S; FAC; INT; (00514).

Sapotaceae

Sideroxylon lycioides L. (Buckthorn)—1; {BV}; S; FACW; SOUTH; (^).

Scrophulariaceae

Gratiola quartermaniae D. Estes (Limestopn Hedge Hyssop)—6; {**GS/SM**}; R; NI; INT; (00342).

Leucospora multifida (Michx.) Nutt. (Narrowleaf Paleseed)—1,4,5,7,8,9,10; {DG, **GS/SM**}; F; OBL; WEST; (00150).

Mecardonia acuminata (Walt.) Small (Axilflower)—1,4,7,8,10; {DG, **GS/SM**}; O; FACW; SOUTH; (00158).

Solanaceae

Physalis pubescens L. (Husk Tomato)—1; {**GS/SM**}; R; UPL; INT; (00186).

Solanum ptycanthemum Dunal (West Indian Nightshade)—1; {**GS/SM**}; R; FACU; INT; (00180).

Ulmaceae

Celtis occidentalis L. (Northern Hackberry)—1; {BV}; S; FACU; NORTH; (^).

Ulmus alata Michx. (Winged Elm)—1,4,5,9; {BV}; S; FACU; INT; (00193).

Ulmus rubra Muhl. (Slippery Elm)—1; {BV}; S; FAC; INT; (^).

Urticaceae

Pilea pumila (L.) Gray (Canadian Clearweed)—1; {BV, **GS/SM**}; S; FACW; INT; (00183).

Verbenaceae

Glandularia canadensis (L.) Nutt. (Rose Mock Vervain)—6; {DG}; S; NI; WEST; (00344).

Verbena simplex Lehm. (Narrowleaf Vervain)—1,4,5,6,10; {DG, **GS/SM**}; F; NI; INT; (00439).

Vitaceae

Parthenocissus quinquefolia (L.) Planch. (Virginia Creeper)—1,3,5,6,7,8; {BV}; O; FAC; INT; (^).

APPENDIX B

Mean Percent Cover Values for Cover Classes in Spring and Summer

MEAN PERCENT COVER VALUES FOR COVER CLASSES IN SPRING AND SUMMER

Mean percent cover values for each cover class were determined for each transect at each site. Transect habitat is given in brackets followed by the number of quadrats the cover class was found in, and the mean percent cover for the indicated cover class within those quadrats.

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Number of Plots	**10**	**5**	**5**	**10**	**10**	**10**	**15**	**10**	**10**	**10**
Species Richness	**77**	**25**	**29**	**62**	**52**	**48**	**51**	**50**	**47**	**63**
Total Rare Species	**5**	**3**	**2**	**7**	**6**	**6**	**6**	**3**	**6**	**7**
Spring										
Allium sp. nov.			{DG} 1, 1		{SM} 4, 7 {SM} 4, 11.4		{DG} 5, 15.6 {GS} 5, 39.4 {SM} 5, 22.6			{DG} 1, 0
Aster sp.		{SM} 1, 0.8				{DG} 3, 2.4			{GS} 1, 2.2	{SM} 1, 0

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Carex crawei						{SM} 4, 38.4		{SM} 1, 3.4	{GS} 5, 3.6	
Carex granularis				{SM} 1, 0.6						
Chamaecrista fasciculata		{SM} 2, 0.2								
Chamasyce spp.	{GS-1} 2, 0.2									
Chrysanthemum leucanthemum						{SM} 1, 0.2				
Clinopodium arkansanum						{SM} 4, 21.4			{GS} 4, 4	
Clinopodium glabellum				{SM} 4, 6.2						
Croton capitatus/ monanthogynus	{GS-2} 1, 0		{DG} 2, 0.4	{DG} 3, 0.2				{DG} 2, 0.2 { SM} 1, 0	{DG} 1, 0 {GS} 2, 0.4	{DG} 1, 0.2
Dalea gattingeri				{DG} 5, 10.8	{SM} 4, 11.6	{DG} 5, 14	{DG} 4, 5 {SM} 4, 9.8	{DG} 5, 7.4	{DG} 5, 10.2 {GS} 2, 0.6	{DG} 5, 14.6

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Delphinium carolinianum ssp. *calciphilum*									{GS} 1, 0.2	
Dicanthelium malacophyllum		{SM} 1, 2.4	{DG} 2, 3.8							
Diodia teres	{GS-1} 5, 34	{SM} 5, 11.4	{DG} 1, 1.8	{DG} 3, 0.8		{DG} 5, 6.2		{DG} 1, 1.2	{GS} 1, 0	{DG} 2, 3.2
	{GS-2} 1, 0.8							{SM} 1, 0		
Eleocharis bifida	{GS-2} 3, 12.8	{SM} 4, 47.2		{SM} 5, 73.2	{SM} 4, 35	{SM} 2, 26.6		{SM} 5, 60.8		{SM} 5, 52.4
					{SM} 5, 22.8					
Erigeron strigosus			{DG} 5, 6.6	{SM} 1, 0.2	{SM} 1, 0.4		{SM} 1, 2.2		{DG} 2, 1.8	{SM} 1, 1
									{GS} 1, 5.2	
Grass sp?	{GS-1} 5, 25									{DG} 4, 26.4
Gravel	{GS-2} 2, 13	{SM} 1, 8	{DG} 5, 30.2	{DG} 5, 42	{SM} 3, 4.6		{DG} 2, 26.8			{SM} 3, 8
							{DG} 1, 14			

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Houstonia purpurea var. *calycosa*				{SM} 2, 0.4	{SM} 2, 1.2	{SM} 2, 1	{GS} 1, 0.2	{SM} 2, 0		{DG} 1, 0.4
							{SM} 3, 2			
Hypericum dolabriforme		{SM} 1, 1.4								
Hypericum sphaerocarpum		{SM} 2, 0.8	{DG} 5, 24.6	{SM} 4, 7.2	{SM} 2, 0.4	{SM} 1, 0.8	{DG} 5, 3.4	{SM} 3, 8		{DG} 1, 0.2
					{SM} 2, 1.4		{SM} 5, 7.2			{SM} 3, 12.2
Isoetes butleri		{SM} 2, 5								
Juncus filipendulus	{GS-2} 5, 19.8	{SM} 1, 1		{SM} 1, 5.6		{SM} 4, 2.4			{GS} 1, 0	{SM} 1, 2.2
Large Rock/Bedrock					{SM} 4, 9.4	{DG} 5, 54	{DG} 2, 23.6	{DG} 4, 77.2	{DG} 5, 54.6	{DG} 5, 31
					{SM} 1, 4		{SM} 4, 37.4	{SM} 2, 1.6	{GS} 5, 40	{SM} 4, 21
Leavenworthia torulosa	{GS-1} 5, 6.2									
Leucospora multifida	{GS-1} 5, 4.4			{SM} 1, 0				{SM} 1, 0		{SM} 4, 0.6

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Lichen spp.					{SM} 1, 1.6					
Lobelia appendiculata var. *gattingeri*				{SM} 1, 0.2	{SM} 2, 0 {SM} 2, 0.6	{SM} 2, 0	{DG} 3, 0 {GS} 3, 0.2 {SM} 2, 0.6		{DG} 1, 0 {GS} 4, 0.6	{DG} 3, 0.4
Minuartia patula						{DG} 4, 0		{DG} 4, 0.6	{DG} 5, 5.6 {GS} 1, 0	
Mud	{GS-1} 5, 28									
Nostoc commune							{GS} 4, 6.6		{DG} 2, 12	
Nothoscordum bivalve				{DG} 5, 10		{DG} 2, 2.6		{SM} 3, 0.4		
Oenothera macrocarpa										{DG} 5, 20.2
Ophioglossum engelmannii	{GS-1} 1, 0									
Opuntia humifusa			{DG} 1, 6.2							

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Packera anonyma									{DG} 1, 0	
Panicum gattingeri/ flexile										{SM} 1, 0
Pleurochaete squarosa					{SM} 2, 7 {SM} 2, 2.4		{SM} 1, 6.4			
Pediomelum subacaule				{DG} 2, 2.6		{DG} 5, 14.2			{DG} 2, 1.6	{DG} 1, 0.6
Plantago virginica			{DG} 3, 6							
Ruellia humilis				{SM} 1, 0.2	{SM} 3, 4.8	{DG} 1, 0.4	{DG} 3, 2.4	{SM} 2, 1.2	{GS} 4, 10	{DG} 3, 2.6
						{SM} 1, 0	{SM} 1, 1.4			{SM} 1, 0
Schoenolirion croceum					{SM} 3, 0.8				{DG} 1, 0.6	{SM} 1, 2.6
					{SM} 5, 46.8				{GS} 5, 18	
Scuttelaria parvula	{GS-1} 3, 1.6	{SM} 2, 0.4	{DG} 5, 15.2	{SM} 5, 2.4	{SM} 2, 0.8	{SM} 1, 0		{SM} 2, 0.8	{GS} 1, 0.2	
	{GS-2} 1, 3.6				{SM} 2, 1					

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Sedum pulchellum	{GS-1} 4, 0.6		{DG} 2, 0							
Sisyrinchium albidum							{GS} 1, 0 {SM} 1, 0		{GS} 4, 5.6	
Sporobolus vaginiflorus	{GS-2} 5, 48.6	{SM} 2, 21.4	{DG} 1, 4	{SM} 1, 2.4 {DG} 5, 33.8	{SM} 5, 20 {SM} 2, 4.8	{DG} 3, 6.2 {SM} 4, 9.2	{DG} 3, 9.2 {GS} 3, 18.2 {SM} 2, 10.2	{DG} 4, 13.4 {SM} 5, 23.8	{DG} 5, 14 {GS} 5, 9.4	
Unidentified	{GS-2} 1, 1.4			{SM} 1, 0.2						{SM} 1, 0.2
Verbena simplex			{DG} 2, 0.2							{DG} 1, 0.2

Summer

Allium sp. nov.				{SM} 4, 39.6	{SM1} 4, 5.2 {SM2} 3, 2.6		{GS} 5, 35.4 {SM} 5, 24.5	{SM} 5, 29.4		{SM} 5, 34.6

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Ambrosia artemisiifolia				{SM} 1, 0.8						{SM} 3, 4.2
Aster sp.							{GS} 2, 1.0 {SM} 5, 4.8	{SM} 1, 0.2	{GS} 2, 1.4	
Chamaecrista fasciculata										{SM} 1, 0.4
Chamaesyce spp.					{SM1} 3, 1.4		{GS} 1, 0.4			
Croton capitatus		{SM} 1, 0.2	{DG} 2, 1.4	{DG} 3, 2.2	{SM1} 1, 0.6 {SM2} 3, 1.8		{SM} 1, 0.2	{SM} 1, 0.2	{GS} 2, 0.8 {DG} 4, 5.4	
Croton monanthogynus				{SM} 1, 0.2	{SM1} 3, 0.8 {SM2} 1, 0.8		{SM} 1, 0.2		{DG} 3, 1.6	
Cyperus squarrosus	{GS1} 3, 6.2	{SM} 4, 8.4								

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Dalea gattingeri				{DG} 4, 4.8	{SM2} 1, 0.2		{DG} 4, 5.8 {SM} 3, 2.6	{DG} 4, 9.2	{GS} 5, 13 {DG} 2, 2.2	{DG} 5, 19.2
Dicanthelium laxiflorum				{DG} 1, 1.0						
Dicanthelium malacophyllum				{DG} 1, 0.60 {SM} 1, 4.1			{SM} 2, 0.6			
Diodia teres	{GS1} 4, 7 {GS2} 2, 12.8		{DG} 1, 0.2		{SM2} 1, 0.2		{SM} 2, 3.2			{DG} 1, 1
Eleocharis bifida					{SM1} 5, 26.2 {SM2} 4, 6.2		{SM} 2, 1.4			
Erigeron strigosus							{DG} 1, 0.2 {SM} 4, 4.0		{DG} 1, 0.6	

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Euphorbia dentata			{DG} 1, 0.2	{DG} 1, 0.40			{GS} 1, 0.2			{DG} 1, 0.8
Gravel				{DG} 5, 44.0			{DG} 5, 60.9	{DG} 5, 57.2 {SM} 1, 8.6	{DG} 1, 11.8	
Grindelia lanceolata				{DG} 1, 0.6 {SM} 1, 0.2						{DG} 3, 3.4
Ground	{GS1} 5, 28.6 {GS2} 3, 9	{SM} 4, 34.8	{DG} 1, 4	{DG} 2, 0.4 {SM} 1, 0.4	{SM1} 3, 9.2 {SM2} 3, 2.6		{DG} 1, 0.2 {GS} 2, 7.2 {SM} 5, 30.7	{SM} 4, 17.6		{SM} 5, 17.4
Heliotropium tennelum							{SM} 5, 2.8		{DG} 3, 2	
Hypericum sphaerocarpum			{DG} 3, 1.6		{SM1} 2, 3.8 {SM2} 1, 0.2		{DG} 3, 1.8 {SM} 2, 3.8	{SM} 5, 21.6		{SM} 5, 30.2

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Isanthus brachiatus							{DG} 5, 9.8		{GS} 4, 2.6	
Large Rock/Bedrock		{SM} 1, 19.6		{DG} 2, 1.6	{SM1} 1, 11.4 {SM2} 3, 39		{GS} 3, 37 {DG} 4, 8.6	{DG} 2, 77	{GS} 5, 52.6 {DG} 4, 40.8	{DG} 5, 33.8
Leaf litter				{DG} 2, 1.8	{SM1} 2, 9.8		{DG} 1, 1.2			
Leavenworthia sp.		{SM} 2, 0.8								
Leucospora multifida					{SM2} 2, 0.4		{GS} 2, 2	{SM} 1, 0.2	{GS} 2, 0.4	
Lobelia appendiculata					{SM1} 1, 0.2		{GS} 1, 0.2			
Pleurochaete squarrosa				{DG} 2, 5.6				{SM} 1, 1	{DG} 2, 6.6	
Nostoc commune				{DG} 1, 0.8			{DG} 3, 1.6			
Oenothera macrocarpa										{DG} 5, 13.8
Ophioglossum engelmannii	{GS1} 1, 0.2									

	FNP 1	FNP 2	FNP 3	Couchville	S46	G139	G137	G138	Sunnybell	Overbridge
Panicum flexile/ gattingeri	{GS1} 5, 44.8 {GS2} 5, 57.8	{SM} 4, 17.4	{DG} 5, 89.6	{SM} 2, 1.6	{SM1} 3, 10.6 {SM2} 5, 27.2		{GS} 5, 11.4 {SM} 2, 1.2	{SM} 3, 3	{GS} 5, 9.6 {DG} 4, 3	{DG} 1, 0.4 {SM} 1, 0.6
Rosa carolina										{SM} 1, 0.2
Ruellia humilis					{SM1} 4, 3.6 {SM2} 3, 1.4		{SM} 5, 3.0	{SM} 1, 0.4	{DG} 3, 3.2	{DG} 1, 0.2
Sisyrinchium albidum							{SM} 1, 0.60			
Sporobolus vaginiflorus	{GS1} 3, 6 {GS2} 4, 20.4	{SM} 2, 18.8	{DG} 1, 1.6	{SM} 5, 52.9 {DG} 5, 36.1	{SM1} 4, 17.2 {SM2} 5, 17.4		{DG} 4, 8.2 {GS} 3, 5.2 {SM} 5, 16.4	{DG} 3, 4.7 {SM} 5, 17.8	{GS} 5, 19.6 {DG} 5, 22.8	{DG} 5, 27.4 {SM} 2, 4.8
Symphyotricum priceae										{SM} 3, 7.6
Unidentified			{DG} 1, 1.4	{SM} 1, 0.2						

APPENDIX C

Photographs of Study Sites

STUDY SITE PHOTOGRAPHS

Flatrock Glade State Nature Preserve, Simpson Co., Ky. Study site 1 (top) and 2 (bottom). Photographs taken September, 2009. FNP 1 was dominated by *Panicum flexile/gattingeri* (44.8%) in the shorter areas and (57.8%) in the longer areas around the edge. *Sporobolus vaginflorus* was a co-dominant in the areas around the edge (20.4%). FNP 2 was also dominated by *P. flexile/gattingeri* (17.4%) and *Sporobolus vaginiflorus* (18.8%).

Flatrock Glade State Nature Preserve, Simpson Co., Ky. Study site 3. Photographs taken Spetember, 2009. FNP study site 3 was a dry glade control dominated by *Panicum flexile/gattingeri* (89.6%).

Flatrock Glade State Nature Preserve, Simpson Co., Ky. Study site 1 (top) and 2 (bottom). Photographs taken June, 2009. FNP 1 was dominated by *Diodia teres* (34%), bare ground (28%) and *Dichanthelium acuminatum* (25%) in the area with short vegetation (foreground). Taller vegetation areas surrounding the shorter vegetation were dominated by *Sporobolus vaginiflorus* (48.6%) and *Juncus filipendulus* (19.8%). FNP 2 had an abundance of exposed bedrock (forground) surrounded by wet areas which were dominated by *Eleocharis bifida* (47.2%) and *Sporobolus vaginiflorus* (21.4%).

Flatrock Glade State Nature Preserve, Simpson Co., Ky. Study site 3. Photographs taken June, 2009. FNP 3 was a dry glade control dominated by *Hypericum sphaerocarpum* (24.6%) and *Scuttelaria parvula* (15.2%).

Couchville Cedar Glade State Natural Area, Davidson Co., TN. Photographs taken May, 2010. The seasonally wet area to the left of the exposed bedrock streambed was dominated by *Eleocharis bifida* (73.2%). The dry glade to the right of the stream bed was dominated by *Allium* sp. nov. (39.4%), Gravel (35.4%) and *Sporobolus vaginiflorus* (18.2%).

Couchville Cedar Glade State Natural Area, Davidson Co., TN. Photographs taken August, 2009 (top) and July 2010 (bottom). Summer dominants in the seasonally wet community included *Sporobolus vaginiflorus* (52.9%).

Cedars of Lebanon State Natural Area, Wilson Co., TN. Site S46. Photographs taken May, 2009. Dominant vegetation included *Schoenolirion croceum* (46.8%) and *Eleocharis bifida* (22.8%).

Cedars of Lebanon State Natural Area, Wilson Co., TN. Site S46. Photographs taken August, 2009. Summer dominant taxa included *Panicum flexile/gattingeri* (10.6% - 27.2%) and *Sporobolus vaginiflorus* (17.3%). *Allium* sp. nov. was also very abundant at the site.

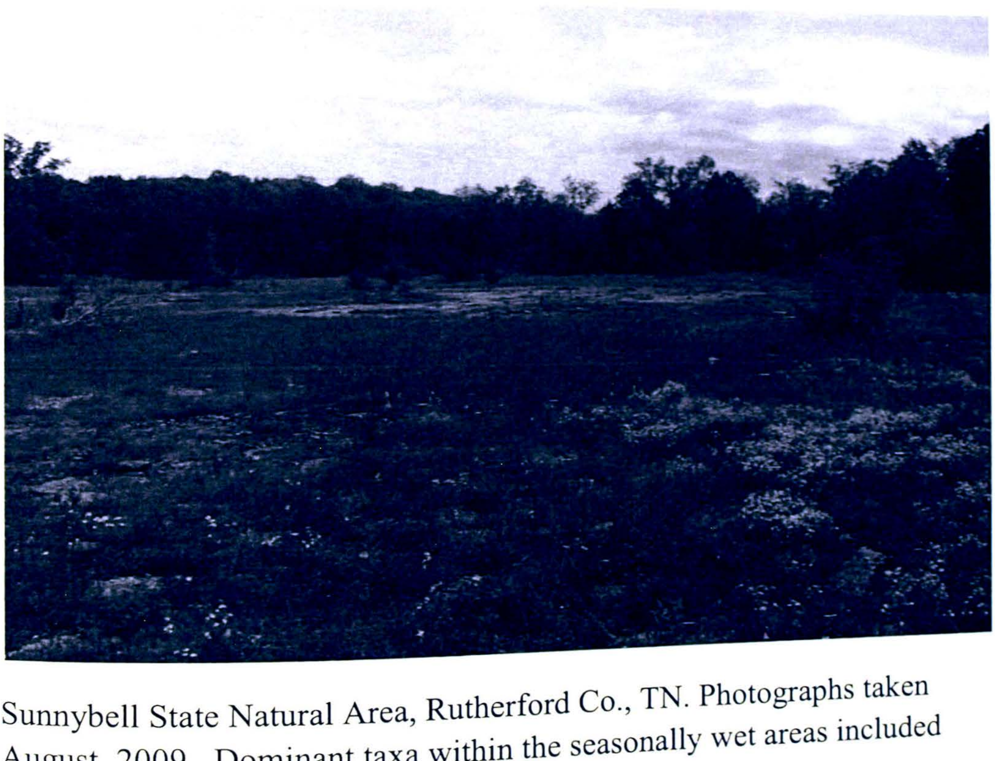
Cedars of Lebanon State Forest, Wilson Co., TN. Site G139. Photographs taken May, 2010. Dominant vegetation in the seasonally wet areas included *Carex crawei* (38.4%), *Eleocharis bifida* (26.6%), and *Clinopodium arkansanum* (21.4%).

Cedars of Lebanon State Forest. Wilson Co., TN. Site G137. Photographs taken August, 2009. Dominant vegetation in the seasonally wet areas included *Allium* sp. nov. (24.5% - 35.4%).

Cedars of Lebanon State Forest. Wilson Co., TN. Site G137. Photographs taken May, 2009. Dominant vegetation in the seasonally wet areas included *Allium* sp. nov. (22.6% - 39.4%).

Cedars of Lebanon State Forest. Wilson Co., TN. Site G138. Photographs taken August, 2009. Dominant vegetation within the seasonally wet areas included *Allium* sp. nov. (29.4%), *Hypericum sphaerocarpum* (21.6%) and *Sporobolus vaginiflorus* (17.8%).

Cedars of Lebanon State Forest. Wilson Co., TN. Site G138. Photographs taken May, 2009. The dominant taxon within the seasonally wet areas was *Eleocharis bifida* (60.8%).



Sunnybell State Natural Area, Rutherford Co., TN. Photographs taken August, 2009. Dominant taxa within the seasonally wet areas included *Sporobolus vaginiflorus* (19.6%).

Sunnybell State Natural Area, Rutherford Co., TN. Photographs taken May, 2010. Dominant species within the seasonally wet community included *Schoenolirion croceum* (18%) and *Ruellia humilis* (10%).

Overbridge State Natural Area, Rutherford Co., TN. Photographs taken August, 2010. Dominant vegetation within the seasonally wet community included *Allium* sp. nov. (34.6%), and *Hypericum sphaerocarpum* (30.2%)

Overbridge State Natural Area, Rutherford Co., TN. Photographs taken May, 2010. Dominant vegetation in the seasonally wet community included *Eleocharis bifida* (52.4%) and *Hypericum sphaerocarpum* (12.2%).

APPENDIX D

Assessment of Vegetation Indicators for Spring Vegetation Quadrats

APPENDIX D

ASSSESSMENT OF VEGETATION INDICATORS FOR SPRING VEGETATION QUADRATS

Vegetation analysis data showing percent cover values for all cover classes within branch 4 of the spring vegetation analysis. This branch was determined to be equivalent to the GS habitat type characterized by NatureServe (2009). Wetland codes were assigned to each species and dominant taxa within each quadrat were determined using the 50/20 rule (USACE 2008). *Eleocharis bifida* was designated a code of OBL as previously discussed. Vegetation indicator 2 was then applied to all quadrats with 46 of 59 quadrats satisfying this indicator. Indicator 3 was then applied to the remaining quadrats, with 2 additional quadrats meeting this indicator. A total of 81.4 percent of quadrats in branch 4 satisfy a vegetation indicator necessary for wetland determination.

Quadrat	Cover Class (Species, abiotic element, etc.)	Percent Cover	Wetland Code	Dominant Taxon	Hydrophytic Vegetation Indicator Met
CouchvilleSM15A	*Eleocharis bifida*	89	*OBL*	x	2
	Scutellaria parvula	6	FACU		
	Hypericum sphaerocarpum	3	FACU		
	Clinopodium glabellum	2	NI		
CouchvilleSM18A	*Eleocharis bifida*	89	*OBL*	x	2
	Hypericum sphaerocarpum	8	FACU		
	Scutellaria parvula	2	FACU		
	Clinopodium glabellum	1	NI		
CouchvilleSM6B	*Eleocharis bifida*	98	*OBL*	x	2
	Clinopodium glabellum	1	NI		
	Scutellaria parvula	1	FACU		
Ky2SM45A	*Eleocharis bifida*	98	*OBL*	x	2
	Diodia teres	2	FACU		
OverbridgeSM6B	*Eleocharis bifida*	73	*OBL*	x	2
	Ground	11			
	Juncus filipendulus	11	FAC		
	Erigeron strigosus var. *calcicola*	5	FAC		

Quadrat	Cover Class (Species, abiotic element, etc.)	Percent Cover	Wetland Code	Dominant Taxon	Hydrophytic Vegetation Indicator Met
G138SM12B	*Eleocharis bifida*	75	*OBL*	x	2
	Sporobolus vaginiflorus	23	UPL	X	
	Ruellia humilis	2	FACU		
G138SM6A	*Eleocharis bifida*	81	*OBL*	x	2
	Sporobolus vaginiflorus	13	UPL		
	Ruellia humilis	4	FACU		
	Scutellaria parvula	2	FACU		
S46SM-2 36B	*Eleocharis bifida*	68	*OBL*	x	2
	Sporobolus vaginiflorus	17	UPL		
	Allium sp. nov.	6	NI		
	Ruellia humilis	6	FACU		
	Scutellaria parvula	2	FACU		
G138SM18A	*Eleocharis bifida*	58	*OBL*	x	2
	Sporobolus vaginiflorus	20	UPL	x	
	Carex crawei	17	OBL		
	Rock	5			
S46SM-2 36A	*Sporobolus vaginiflorus*	35	UPL	x	2
	Eleocharis bifida	33	*OBL*	x	
	Allium sp. nov.	13	NI		
	Rock	10			
	Dalea gattingeri	7	NI		
	Schoenolirion croceum	2	OBL		
OverbridgeSM15A	*Eleocharis bifida*	45	*OBL*	x	2
	Rock	44			
	Hypericum sphaerocarpum	8	FACU		
	Leucospora multifida	2	OBL		
OverbridgeSM9A	*Eleocharis bifida*	52	*OBL*	x	2
	Rock	46			
	Leucospora multifida	1	OBL		
G139SM12A	*Eleocharis bifida*	80	*OBL*	x	2
	Sporobolus vaginiflorus	12	UPL		
	Houstonia purpurea var. *calycosa*	4	NI		
	Hypericum sphaerocarpum	4	FACU		
G138SM36A	*Eleocharis bifida*	55	*OBL*	x	3
	Sporobolus vaginiflorus	20	UPL	x	
	Hypericum sphaerocarpum	19	FACU	x	
	Ground	3			
	Scutellaria parvula	2	FACU		
	Nothoscordum bivalve	1	FAC		

Quadrat	Cover Class (Species, abiotic element, etc.)	Percent Cover	Wetland Code	Dominant Taxon	Hydrophytic Vegetation Indicator Met
G138SM45B	*Sporobolus vaginiflorus*	43	UPL	x	
	Eleocharis bifida	35	*OBL*	x	
	Hypericum sphaerocarpum	21	FACU	x	
	Nothoscordum bivalve	1	FAC		
OverbridgeSM18A	*Eleocharis bifida*	46	*OBL*	x	2
	Hypericum sphaerocarpum	32	FACU	x	
	Rock	24			
OverbridgeSM27B	*Eleocharis bifida*	46	*OBL*	x	2
	Hypericum sphaerocarpum	21	FACU	x	
	Rock	20			
	Schoenolirion croceum	13	OBL		
Ky1GS-2 21B	*Sporobolus vaginiflorus*	41	UPL	x	2
	Eleocharis bifida	39	*OBL*	x	
	Scutellaria parvula	18	FACU		
	Juncus filipendulus	2	FAC		
Ky3DG6A	Ground	46			
	Scutellaria parvula	26	FACU	x	
	Hypericum sphaerocarpum	20	FACU	x	
	Allium sp. nov.	5	NI		
	Erigeron strigosus var. *calcicola*	3	FAC		
CouchvilleSM36B	*Eleocharis bifida*	63	*OBL*	x	2
	Hypericum sphaerocarpum	19	FACU		
	Sporobolus vaginiflorus	12	UPL		
	Houstonia purpurea var. *calycosa*	2	NI		
	Unidentified	1			
	Ruellia humilis	1	FACU		
	Scutellaria parvula	1	FACU		
S46SM-2 9A	*Eleocharis bifida*	46	*OBL*	x	2
	Sporobolus vaginiflorus	22	UPL	x	
	Lichen spp.	8			
	Dalea gattingeri	7	NI		
	Ruellia humilis	7	FACU		
	Rock	5			
	Pleurochaete squarrosa	4			
	Hypericum sphaerocarpum	1	FACU		
	Schoenolirion croceum	1	OBL		
G137W-GS12A	*Allium* sp. nov.	31	NI	x	
	Sporobolus vaginiflorus	28	UPL	x	

Quadrat	Cover Class (Species, abiotic element, etc.)	Percent Cover	Wetland Code	Dominant Taxon	Hydrophytic Vegetation Indicator Met
	Rock	26			
	Nostoc commune	15			
G137W-GS27B	*Allium* sp. nov.	50	NI	x	
	Rock	38		x	
	Nostoc commune	12			
G137W-GS33A	*Allium* sp. nov.	61	NI	x	
	Rock	39			
G137W-GS39B	*Sporobolus vaginiflorus*	50	UPL	x	
	Allium sp. nov.	32	NI	x	
	Ground	16			
	Houstonia purpurea var. *calycosa*	1	NI		
	Lobelia appendiculata var. *gattingeri*	1	FAC		
G137W-SM1B	*Sporobolus vaginiflorus*	36	UPL	x	
	Allium sp. nov.	35	NI	x	
	Erigeron strigosus var. *calcicola*	11	FAC		
	Hypericum sphaerocarpum	9	FACU		
	Houstonia purpurea var. *calycosa*	6	NI		
	Lobelia appendiculata var. *gattingeri*	2	FAC		
S46112B	*Schoenolirion croceum*	43	OBL	x	2
	Eleocharis bifida	29	*OBL*	x	
	Sporobolus vaginiflorus	14	UPL		
	Allium sp. nov.	9	NI		
	Lobelia appendiculata var. *gattingeri*	3	FAC		
	Scutellaria parvula	2	FACU		
S46SM-1 27B	*Schoenolirion croceum*	54	OBL	x	2
	Rock	20			
	Pleurochaete squarrosa	12			
	Sporobolus vaginiflorus	10	UPL		
	Scutellaria parvula	3	FACU		
	Eleocharis bifida	1	*OBL*		
S46SM-1 3A	*Schoenolirion croceum*	60	OBL	x	2
	Eleocharis bifida	27	*OBL*	x	
	Ground	8			
	Hypericum sphaerocarpum	5	FACU		
S46SM-1 6A	*Schoenolirion croceum*	41	OBL	x	2
	Eleocharis bifida	26	*OBL*	x	

Quadrat	Cover Class (Species, abiotic element, etc.)	Percent Cover	Wetland Code	Dominant Taxon	Hydrophytic Vegetation Indicator Met
	Allium sp. nov.	19	NI	x	
	Ground	12			
	Hypericum sphaerocarpum	2	FACU		
S46SM-1 9A	*Schoenolirion croceum*	36	OBL	x	2
	Eleocharis bifida	31	*OBL*	x	
	Allium sp. nov.	29	NI	x	
	Ground	3			
Ky1GS-2 15A	*Sporobolus vaginiflorus*	71	UPL	x	
	Juncus filipendulus	18	FAC		
	Eleocharis bifida	11	*OBL*		
Ky1GS-2 48A	*Sporobolus vaginiflorus*	75	UPL	x	2
	Juncus filipendulus	25	FAC	x	
Ky1GS-2 42B	*Sporobolus vaginiflorus*	49	UPL	x	2
	Juncus filipendulus	29	FAC	x	
	Eleocharis bifida	14	*OBL*		
	Ground	8			
Ky1GS-2 6A	Ground	57			2
	Juncus filipendulus	25	FAC	x	
	Sporobolus vaginiflorus	7	UPL		
	Diodia teres	4	FACU		
Ky2SM36B	Ground	40			2
	Eleocharis bifida	36	*OBL*	x	
	Isoetes butleri	14	OBL	x	
	Diodia teres	5	FACU		
	Juncus filipendulus	5	FAC		
Ky2SM9A	*Sporobolus vaginiflorus*	65	UPL	x	
	Diodia teres	24	FACU	x	
	Isoetes butleri	11	OBL		
Ky21SM5A	*Eleocharis bifida*	47	*OBL*	x	2
	Sporobolus vaginiflorus	42	UPL	x	
	Diodia teres	10	FACU		
	Chamaecrista fasiculata	1	FACU		
G137W-SM21A	*Pleurochaete squarrosa*	32		x	
	Allium sp. nov.	26	NI	x	
	Dalea gattingeri	11	NI		
	Rock	10			
	Hypericum sphaerocarpum	9	FACU		
	Ruellia humilis	7	FACU		
	Houstonia purpurea var. *calycosa*	4	NI		

Quadrat	Cover Class (Species, abiotic element, etc.)	Percent Cover	Wetland Code	Dominant Taxon	Hydrophytic Vegetation Indicator Met
	Lobelia appendiculata var. *gattingeri*	1	FAC		
S46SM-2 15A	*Pleurochaete squarrosa*	31		x	
	Dalea gattingeri	21	NI	x	
	Allium sp. nov.	13	NI		
	Ruellia humilis	11	FACU		
	Rock	9			
	Sporobolus vaginiflorus	8	UPL		
	Houstonia purpurea var. *calycosa*	5	NI		
	Scutellaria parvula	2	FACU		
G139SM21A	*Carex crawei*	84	OBL	x	2
	Clinopodium arkansanum	7	FACW		
	Juncus filipendulus	5	FAC		
	Sporobolus vaginiflorus	3	UPL		
	Houstonia purpurea var. *calycosa*	1	NI		
G139SM27A	*Carex crawei*	57	OBL	x	2
	Clinopodium arkansanum	25	FACW	x	
	Sporobolus vaginiflorus	13	UPL		
	Juncus filipendulus	5	FAC		
G139SM30A	*Clinopodium arkansanum*	58	FACW	x	2
	Carex crawei	42	OBL	x	
G139SM30B	*Eleocharis bifida*	53	*OBL*	x	2
	Sporobolus vaginiflorus	18	UPL		
	Clinopodium arkansanum	17	FACW		
	Carex crawei	9	OBL		
	Juncus filipendulus	2	FAC		
	Chrysanthemum leucanthemum	1	UPL		
SunnybellSM27A	*Schoenolirion croceum*	39	OBL	x	3
	Sporobolus vaginiflorus	18	UPL	x	
	Sisyrinchium albidum	17	FACU	x	
	Rock	15			
	Carex crawei	5	OBL		
	Clinopodium arkansanum	2	FACW		
	Ruellia humilis	2	FACU		
	Croton capitatus/monanthogynus	1	NI		
	Dalea gattingeri	1	NI		
SunnybellSM45A	Rock	58			2

Quadrat	Cover Class (Species, abiotic element, etc.)	Percent Cover	Wetland Code	Dominant Taxon	Hydrophytic Vegetation Indicator Met
	Schoenolirion croceum	12	OBL	x	
	Clinopodium arkansanum	10	FACW	x	
	Sisyrinchium albidum	8	FACU		
	Ruellia humilis	6	FACU		
	Carex crawei	3	OBL		
	Sporobolus vaginiflorus	3	UPL		
SunnybellSM9B	Ground	36			2
	Erigeron strigosus var. *calcicola*	26	FAC	x	
	Schoenolirion croceum	17	OBL	x	
	Sporobolus vaginiflorus	11	UPL		
	Carex crawei	4	OBL		
	Sisyrinchium albidum	3	FACU		
	Dalea gattingeri	2	NI		
	Croton capitatus/monanthogynus	1	NI		

APPENDIX E

Assessment of Vegetation Indicators for Study Sites

APPENDIX E

ASSSESSMENT OF VEGETATION INDICATORS FOR STUDY SITES

Spring vegetation analysis data based on percent cover data using the photographic method. Frequency equals the number of quadrats the cover class occurs in within the indicated transect. Abundance refers to the mean percent cover for the indicated cover class within the given transect. [!]-indicates a dominant taxon according to the 50/20 rule for determining dominants (USACE 2008). Vegetation indicators were applied to each seasonally wet habitat at each site. Any vegetation indicator satisfied was noted.

Habitat	Cover Class (Species, abiotic element, etc.)	Frequency	Abundance (%)	Wetland Code	Vegetation Indicator Met
	Couchville				
SM	[!]*Eleocharis bifida*	5	73.20	*OBL*	2
	Hypericum sphaerocarpum	4	7.20	FACU	
	Clinopodium glabellum	4	6.20	NI	
	Juncus filipendulus	1	5.60	FAC	
	Scutellaria parvula	5	2.40	FACU	
	Sporobolus vaginiflorus	1	2.40	UPL	
	Carex granularis	1	0.60	FACW	
	Houstonia purpurea var. *calycosa*	2	0.40	NI	
	Erigeron strigosus	1	0.20	FAC	
	Unidentified	1	0.20		
	Lobelia appendiculata var. *gattingeri*	1	0.20	FAC	
	Ruellia humilis	1	0.20	FACU	
	Leucospora multifida	1	0.00	OBL	
	G137				
GS	[!]*Allium* sp. nov.	5	39.40	NI	---

Habitat	Cover Class (Species, abiotic element, etc.)	Frequency	Abundance (%)	Wetland Code	Vegetation Indicator Met
	Gravel/Ground	5	35.40		
	'*Sporobolus vaginiflorus*	3	18.20	UPL	
	Nostoc commune	4	6.60		
	Houstonia purpurea var. *calycosa*	1	0.20	NI	
	Lobelia appendiculata var. *gattingeri*	3	0.20	FAC	
	Sisyrinchium albidum	1	0.00	FACU	
SM	Rock	4	37.40		---
	'*Allium* sp. nov.	5	22.60	NI	
	'*Sporobolus vaginiflorus*	2	10.20	UPL	
	Dalea gattingeri	4	9.80	NI	
	Hypericum sphaerocarpum	5	7.20	FACU	
	Pleurochaete squarrosa	1	6.40		
	Erigeron strigosus	1	2.20	FAC	
	Houstonia purpurea var. *calycosa*	3	2.00	NI	
	Ruellia humilis	1	1.40	FACU	
	Lobelia appendiculata var. *gattingeri*	2	0.60	FAC	
	Sisyrinchium albidum	1	0.00	FACU	
G138					
SM	'*Eleocharis bifida*	5	60.80	*OBL*	2
	'*Sporobolus vaginiflorus*	5	23.80	UPL	
	Hypericum sphaerocarpum	3	8.00	FACU	
	Carex crawei	1	3.40	OBL	
	Ruellia humilis	2	1.20	FACU	
	Rock/Ground	2	1.60		
	Scutellaria parvula	2	0.80	FACU	
	Nothoscordum bivalve	3	0.40	FAC	

Habitat	Cover Class (Species, abiotic element, etc.)	Frequency	Abundance (%)	Wetland Code	Vegetation Indicator Met
	Croton spp.	1	0.00		
	Dalea gattingeri	1	0.00	NI	
	Houstonia purpurea var. *calycosa*	2	0.00	NI	
	Leucospora multifida	1	0.00	OBL	
	G139				
SM	!*Carex crawei*	4	38.40	OBL	2
	!*Eleocharis bifida*	2	26.60	*OBL*	
	!*Clinopodium arkansanum*	4	21.40	FACW	
	Sporobolus vaginiflorus	4	9.20	UPL	
	Juncus filipendulus	4	2.40	FAC	
	Houstonia purpurea var. *calycosa*	2	1.00	NI	
	Hypericum sphaerocarpum	1	0.80	FACU	
	Leucanthemum vulgare	1	0.20	UPL	
	Lobelia appendiculata var. *gattingeri*	2	0.00	FAC	
	Ruellia humilis	1	0.00	FACU	
	Scutellaria parvula	1	0.00	FACU	
	FNP 1				
GS-1	!*Diodia teres*	5	34.00	FACU	2
	Mud	5	28.00		
	!*Dichanthelium acuminatum*	5	25.00	FAC	
	Leavenworthia torulosa	5	6.20	FACU	
	Leucospora multifida	5	4.40	OBL	
	Scutellaria parvula	3	1.60	FACU	
	Sedum pulchellum	4	0.60	UPL	
	Chamaesyce spp.	2	0.20		
	Ophioglossum engelmannii	1	0.00	FACU	
GS-2	!*Sporobolus vaginiflorus*	5	48.60	UPL	2

Habitat	Cover Class (Species, abiotic element, etc.)	Frequency	Abundance (%)	Wetland Code	Vegetation Indicator Met
	!*Juncus filipendulus*	5	19.80	FAC	
	Ground	2	13.00		
	Eleocharis bifida	3	12.80	*OBL*	
	Scutellaria parvula	1	3.60	FACU	
	Unidentified seedlings	1	1.40		
	Diodia teres	1	0.80	FACU	
	Croton spp.	1	0.00		
		FNP 2			
SM	!*Eleocharis bifida*	4	47.20	*OBL*	2
	!*Sporobolus vaginiflorus*	2	21.40	UPL	
	Diodia teres	5	11.40	FACU	
	Ground	1	8.00		
	Isoetes butleri	2	5.00	OBL	
	Dichanthelium malacophyllum	1	2.40	NI	
	Hypericum dolabriforme	1	1.40	NI	
	Juncus filipendulus	1	1.00	FAC	
	Aster spp.	1	0.80		
	Hypericum sphaerocarpum	2	0.80	FACU	
	Scutellaria parvula	2	0.40	FACU	
	Chamaecrista fasiculata	2	0.20	FACU	
		Overbridge			
SM	!*Eleocharis bifida*	5	52.40	*OBL*	2
	Rock	4	21.00		
	Hypericum sphaerocarpum	3	12.20	FACU	
	Ground	3	8.00		
	Schoenolirion croceum	1	2.60	OBL	
	Juncus filipendulus	1	2.20	FAC	
	Erigeron strigosus	1	1.00	FAC	
	Leucospora multifida	4	0.60	OBL	
	Unidentified	1	0.20		
	Aster spp.	1	0.00		

Habitat	Cover Class (Species, abiotic element, etc.)	Frequency	Abundance (%)	Wetland Code	Vegetation Indicator Met
	Panic spp.	1	0.00		
	Ruellia humilis	1	0.00	FACU	
S46					
SM-1	!*Schoenolirion croceum*	5	46.80	OBL	2
	!*Eleocharis bifida*	5	22.80	*OBL*	
	Allium sp. nov.	4	11.40	NI	
	Sporobolus vaginiflorus	2	4.80	UPL	
	Ground	3	4.60		
	Rock	1	4.00		
	Pleurochaete squarrosa	2	2.40		
	Hypericum sphaerocarpum	2	1.40	FACU	
	Scutellaria parvula	2	1.00	FACU	
	Lobelia appendiculata var. *gattingeri*	2	0.60	FAC	
SM-2	!*Eleocharis bifida*	4	35.00	*OBL*	2
	!*Sporobolus vaginiflorus*	5	20.00	UPL	
	Dalea gattingeri	4	11.60	NI	
	Rock	4	9.40		
	Allium sp. nov.	4	7.00	NI	
	Pleurochaete squarrosa	2	7.00		
	Ruellia humilis	3	4.80	FACU	
	Lichen spp.	1	1.60		
	Houstonia purpurea var. *calycosa*	2	1.20	NI	
	Schoenolirion croceum	3	0.80	OBL	
	Scutellaria parvula	2	0.80	FACU	
	Erigeron strigosus	1	0.40	FAC	
	Hypericum sphaerocarpum	2	0.40	FACU	
	Lobelia appendiculata var. *gattingeri*	2	0.00	FAC	
Sunnybell					