Central Hardwoods Joint Venture Glade Conservation Assessment

For the Interior Highlands and Interior Low Plateaus

Of the Central Hardwoods Region

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Front cover photo: McClurg Glade (an Ozark Dolomite Glade) on the Mark Twain National Forest, Taney County, Missouri. Photo by Paul W. Nelson.

Table of Contents:

Introduction:

The glade conservation assessment is a collaborative effort among 8 states to document the current status and distribution of 24 distinct glade ecosystems and their associated species of conservation concern within the Central Hardwoods Bird Conservation Region, as well as the Ouachita Mountains to the south. This area includes portions of the Interior Highlands (Missouri, northern Arkansas, and extreme eastern Oklahoma); Interior Low Plateau Highlands (Tennessee, Kentucky, southern Indiana and Illinois, and northern Alabama); and Interior Low Plateau Bluegrass (Kentucky and Tennessee). The Central Hardwoods Joint Venture, a public-private partnership for bird conservation (see www.chjv.org), has targeted glades and associated glade-woodland complexes as natural communities capable of providing high-quality habitat for several priority bird species, including Prairie Warbler, Blue-winged Warbler, Field Sparrow, Northern Bobwhite, Eastern Wood-Pewee, and others. While the CHJV's mission is to conserve viable populations of priority bird species within the Central Hardwoods Bird Conservation Region, we also recognize the importance of glade complexes in conserving other flora and fauna of conservation concern.

The CHJV assessment region also encompasses U.S. Forest Service lands including the Mark Twain, Shawnee, Hoosier, Ozark-St. Francis, and Ouachita national forests. Thirty-one plant species and 12 animal species are recognized as U.S. Forest Service Regional Forester Sensitive Species (RFSS). Broad-scale conservation assessments are valuable tools that are essential to identifying conservation management actions on Forest Service lands.

This assessment is a necessary first step in identifying those glade complexes that have the greatest potential to satisfy the needs of the broader suite of species that depend on glades for their survival. Respective state conservation agencies, The Nature Conservancy, Natural Heritage Programs, universities, and other entities amassed a list of 207 plant species for which glade habitat is obligate, optimal or suitable for sustaining them. While a number of animal species are associated with glade habitats, they typically are affiliated with the glade/woodlands complexes in which the glades are embedded, rather than being obligate to the glades themselves. Most of these animals also have relatively wide geographic ranges in which they utilize habitats other than glade woodland complexes alone.

This assessment documents what is known and unknown about the species of conservation concern associated with shallow bedrock glade natural communities. It provides the background information needed to develop a plan of action to conserve glade ecosystems and their extant species of conservation concern.

Partners participating in or assisting with this assessment include those possessing information regarding the following:

1. The classification, description, and distribution of glades.
2. Range of natural variability, including historic descriptions for ecological units (Ozark Highlands; St. Francois Mountains, etc.); disturbance processes and regimes.
3. Current condition, threats, and stressors.

4. Glade-affiliated species of conservation concern.
5. Population and Ecosystem Viability.
6. Research, monitoring, and scientific references.

Glade Characteristics:

Glades are open, rocky, barren areas with shallow soils that support unique communities of drought-adapted forbs, warm-season grasses, and a specialized fauna. Glades are most often located on western or southern exposures or on the high summits of ridges, knobs, domes, or escarpments where soils are thin and moisture conditions favor drought-tolerant species, but also can occur in low basins where certain edaphic conditions foster their development. Lichens and mosses occur on exposed rock surfaces, especially on sandstone, chert, and granite.

Glades occur in many regions of North America, especially where prairie adjoins woodland. They range as far north as the St. Croix National Scenic Riverway in Wisconsin and Minnesota where they are found along the steep slopes of river valleys (Glenn-Lewin and Ver Hoef 1988). They extend south into Texas and Louisiana, and from Missouri east through Illinois and Indiana and into the Central Basin of Tennessee and Kentucky, Georgia, Alabama, and Virginia (Baskins and Baskins 2007). Some ecologists view glades as relicts of a more widespread Great Plains flora or remnants of an eastward prairie migration during the post-Wisconsin glacial thermal maximum (Palmer 1921, Steyermark 1934, 1940, 1959). Other authors interpret glades as edaphic (influenced by the nature of soils) climax communities (Erickson et al. 1942, Baskin and Baskin 1999). This assessment encompasses the Interior Highlands of Missouri, Arkansas, and Oklahoma, and the Interior Low Plateaus of southern Illinois, Indiana, central Kentucky and Tennessee, and northern Alabama (see “Glade Distribution and Sensitive Species by Ecological Subsection” later in this assessment for more detail).

Glades in the assessment area can be small (less than .040 ha) to large (607 ha) and typically occur as openings within landscapes primarily dominated by woodlands or forests,
The primary parameter defining glades in this assessment is that the range of physicial, geological and vegetational variations of glades occur on broad areas of solid bedrock near the land surface. Glades are shallow bedrock natural communities or associations. The spatial distribution of herbaceous vegetation into micro-associations on glades is attributed to soil depth and moisture availability (Freeman 1933, Quarterman 1950). Ver Hoef et al. (1993) described 3 soil depths for open glades on rhyolite and Gasconade dolomite in Missouri as rocky, very shallow (0-13 cm), intermediate (13-30 cm), and deep soil zones (30-51 cm). Shallow, gravelly soils support annual forbs and grasses, while perennial grasses and forbs characterize intermediate soil depths on high-quality glades. The following soil, rock, and moisture characteristics and their corresponding vegetation patterns and dominance are adapted from Baskin and Baskin (2007) in part for use in characterizing glade flora and fauna, mapping, inventory, and the assignment of plant and animal species of conservation concern. The glade

area can contain as few as one or two of the following variations or, with more complex glade communities, all of them:

1. Bare rock pavement. Soil depth is nearly zero. Bare exposed bedrock is dominated by mosses and crustose lichens. Ferns and some forbs grow from cracks. Extended rock shelves or benches are often prominent where exposed erosion-resistant sedimentary bedrock (particularly limestones and dolomites) follows elevation contours. Ephemeral seep pools and seep types often occur here. Often drought maintained; last to be encroached on by shrubs and trees.
2. Gravel, silt and organic matter collected around bedrock in soil up to 1 cm deep. Ephemerally wet. Nostoc, *Tortella,* and *Grimmia* mosses; reindeer lichens and annual forbs and grasses are dominant. This often forms along the contact zone between deeper grass and forb-dominated soils and bedrock. Few but specialized vascular plant species including *Talinum*, *Geocarpon*, *Isoetes,* and *Eriocaulon*. Often drought maintained.
3. Established zone of interwoven roots, organic matter and fine gravel-sand over bedrock. Soil 2 to 5 cm deep. *Polytrichum* moss, reindeer moss, annual grasses, and forbs woven together. Vascular plants often include *Leavenworthia*, *Sedum, and Cyperus*. Drought still important but red cedar can invade when overgrazed and fire-suppressed. Scattered and often stunted, open-grown trees can occur often rooting in bedrock fractures or where bedrock is weathered and broken.
4. Perennial grass-dominated; mixed perennial forbs. Soil depth greater than 5 cm. *Andropogon* and *Sporobolus* species form the dominant matrix upon which many mixed perennial forbs prevail. Fire becomes more important in limiting woody invasion. Severe drought often kills deciduous woody invaders and, to a lesser extent, red cedar and Ashe's juniper. Scattered fire-tolerant oaks or shortleaf pine can occur but often are spaced far enough apart to allow for the continuation of warm season grasses and mixed forbs to form a dense groundcover.
5. Interspersed rock shelves and large rock outcrops. These often form extended ledges 0.5 to 2 m high along contours. Variations 1 and 2, above, often occupy a flat rock-exposed shelf above the ledge. Drought-tolerant and fire-sheltered trees occur along rock shelves along with shrubs, vines, and (in crevices) drought-adapted ferns such as *Cheilanthes*, *Pellaea*, *Argyrochosma*, *Asplenium*, and *Woodsia* species.
6. Interspersed trees and tree-dominated borders of glades. As most glades by definition are shallow bedrock openings occurring within a matrix of tree-dominated woodlands or forests (and some prairies), then the historical extent cover and dominance by trees (and invading uncharacteristic woody vegetation) determined their boundaries and soil depth thresholds for the transition between characteristic glade plant associations and dry woodland/cliff natural communities. Historic land survey records and tree aging show that drought-tolerant tree species once covered as much as 30% of larger, more extensive shallow bedrock glades. Mapping glades is especially challenging where bedrock below the surface becomes weathered, fragmented and interspersed with deeper soil pockets. Extensive acreages (in the hundreds of hectares) form tree-dominated rocky woodlands interspersed with glade openings. Some ecologists map them as "complexes" of glades and dry rocky woodlands of variable rock types. With degraded glades, especially those with a history of overgrazing and

fire suppression, trees often invade and form a dense canopy. This canopy closure suppresses former characteristic herbaceous species, evidenced by the presence of an occasional single leaf or two attached to certain suppressed herbaceous species. McCarty and Hassien (1984) documented the presence of glade and woodland prairie plant species occurring in degraded closed canopies and demonstrated their recovery when this invasive woody canopy was thinned and burned.

Range of Natural Variability, Disturbance Processes, and Regimes:

Much has been written in recent decades about the role of natural disturbances such as fire, flooding, and insect outbreaks in structuring ecosystems from grasslands to forests across the United States (Pickett and White 1985; Sweeny 1990) with an ever-increasing emphasis on the role of fire in the region encompassed by and adjacent to this assessment area. The pattern of disturbance across temporal and spatial scales is called the disturbance regime. Through and within limits set by the local landscape and climate, disturbance patterns vary for the variety of glade types distributed across this glade assessment area. Managers and researchers attempt to identify those disturbance regimes that occurred prior to European settlement to better understand the range of dynamics that the systems evolved within, and are considered by some to be the ideal conditions against which altered contemporary landscapes and their composition are evaluated (Noss 1983: McCarty in Nelson 2010).

Disturbance regimes have 6 main elements: frequency, duration, intensity, extent, pattern, and seasonal timing. Each element is a variable which to some extent can be changed or altered independent of the others (McCarty; in Nelson 2010). A characteristic range exists for each disturbance, with both averages and extremes being significant in shaping the character and composition of glade associations. The range of natural variability for each is a function of the physical environment, geology, and landform, and the interaction with other physical and biological features. These are likely similar across the NatureServe Systems under which the respective subsets of glade associations in the Interior Highlands and Interior Low Plateaus evolved. Through the understanding of disturbance regimes, managers can apply a range of management techniques that can help to return structure and function to glade ecosystems.

Fire

Fire is one of the most fundamental historic disturbance processes in all of North America (Pyne 1982). Many early explorers chronicled numerous accounts of periodic fires and their observed effects during early European settlement. Native Americans used fire for numerous purposes, including hunting, clearing fields, and improving mast production (Black and Abrams 2001; Abrams and Nowacki 2008). While pre-settlement fire frequency was highly variable across space and time and dependent to a large degree on variation in climate, sources of ignition, and topographic roughness (Guyette and Dey 2000; Stambaugh and Guyette 2008), models more recently developed by Guyette et al. (2011) based upon climate and fire scar data from 170 sites

across eastern North America suggest potential mean fire intervals ranged from as little as 2 to 8 yr across the assessment region.

With the exception of the Missouri Ozarks, where fire scar data suggest a mean fire return interval of 3.2 yr prior to settlement (Guyette and McGinnes 1982), few studies of fire intervals in glade systems exist to date. However, glade ecosystems in the Interior Highlands and Interior Low Plateaus were and are embedded in fire-prone landscapes that undoubtedly were affected by both high- and low-intensity fires at repeated intervals during their evolution. Arguably, fire remains vital to the health, vegetative structure, composition, and perhaps viability of plant and animal species found with the glades and adjacent woodlands, savannas, and prairies that surround them.

Climatic Fluctuations

Mid-continental climate strongly influences and shapes vegetation associated with shallow bedrock natural communities. Extended drought periods can kill woody plants, keeping woody succession in check (Nelson 2010). Climatic factors facilitate the many disturbance events that shape glades, especially the fire regime and fire behavior (Guyette et al. 2011). The mid-continental location of the CHJV glade assessment region occurs in the western half of the Humid Temperate Domain (Bailey 1995). This domain drives the climate regime of 4 seasons with strong annual cycles of precipitation and temperature. The central hardwoods region addressed in this assessment remained unglaciated during the last glacial period (Wisconsinan), which ended about 12,000 yr ago. Over the past 12,000 yr, this area has experienced warm and cool periods and several extended drought periods and wetter periods. Reconstructions from past millennium tree rings show that several multi-decadal drought periods occurred in the area (Stahle et al. 2000; Stambaugh et al. 2011).

Summers are relatively hot, while winters range from mild to bitterly cold. Within this domain, a precipitation, humidity, and temperature gradient occurs from west to east. Glades in the western portion of the assessment area are subject to increasingly lower humidity and less precipitation (102 cm) while those to the east are generally more humid with precipitation exceeding 152 cm. Thunderstorms often occur under wet, humid conditions with lightning fires limited primarily to the western portion of the assessment area. Delcourt (1998), Nowacki (2008), and others provide in-depth evidence of the role of Native Americans in broadcasting fire, allowing for stable, oak-dominated vegetation in the eastern half of the United States despite climatic shifts from warm wet to cool dry conditions over the past 3,000 yr.

In the Midwest, historic (measured) temperature records exist for only slightly more than 100 years. Year-to-year variation can be influenced by ocean circulation patterns, such as the El Niño Southern Oscillation and the Pacific Decadal Oscillation. Extended drought has occurred in the past, causing woody vegetation bordering the shallowest soils of glades to die back (Nelson 2010). Thirty-year temperature and precipitation averages for the states included in the study are are given below.

Table 1. Thirty-year normals shown in this table (1981-2010 averages) were calculated using the ClimateWizard custom analysis tool (http://climatewizardcustom.org/).

1981-2010 Climate Normals
For Eco Province 223 for Select States

Temperature (Minimum, F)

	Annual	*Winter*	*Spring*	*Summer*	*Fall*
Illinois	45.03	24.77	44.39	65.05	45.92
Ohio	43.30	24.34	41.78	62.57	44.49
Indiana	43.91	24.08	42.87	63.70	45.00
Missouri	44.50	24.19	43.74	64.53	45.54
Kentucky	45.58	26.89	44.41	64.50	46.54
Oklahoma	47.83	28.24	47.10	67.06	48.93
Tennessee	46.68	28.80	45.56	65.09	47.27
Arkansas	46.61	27.55	45.89	65.64	47.38
Alabama	49.00	31.74	48.10	66.74	49.40

Temperature (Maximum, F)

	Annual	*Winter*	*Spring*	*Summer*	*Fall*
Illinois	65.63	41.87	65.71	86.50	68.44
Ohio	64.59	42.03	64.51	84.61	67.23
Indiana	64.80	41.53	64.96	85.15	67.55
Missouri	66.98	44.77	67.28	86.93	68.96
Kentucky	67.18	45.50	67.34	86.33	69.53
Oklahoma	70.17	49.49	69.94	89.26	71.99
Tennessee	69.39	49.34	69.59	87.15	71.48
Arkansas	69.71	48.84	69.74	88.75	71.52
Alabama	71.17	51.88	71.39	88.24	73.17

Precipitation (Inches)

	Annual	*Winter*	*Spring*	*Summer*	*Fall*
Illinois	43.45	8.80	12.82	11.02	11.34
Ohio	43.08	9.17	12.81	11.72	9.57
Indiana	45.58	9.56	13.69	11.70	11.18
Missouri	45.07	8.20	13.19	11.77	12.46
Kentucky	47.67	11.51	13.82	11.70	11.19
Oklahoma	46.31	7.88	13.78	11.86	12.77
Tennessee	53.70	14.42	14.93	12.36	13.13
Arkansas	47.06	10.06	13.70	10.54	13.51
Alabama	56.69	16.07	15.19	12.66	13.98

Soil Frost

Soil frost is a common phenomenon of the relatively shallow soils of glades. All of the glades within the assessment area are subject to this process as temperatures fluctuate between subfreezing and above freezing during late fall, winter, and early spring. Glade soils are particularly susceptible due to significant amounts of fine soil particles and an interwoven moss/ herbaceous mat lying on top of relatively impervious rock. This allows precipitation or seepage often to remain within the shallow soil layer during winter and early spring. Soil freeze and thaw is important to glade soils because it leaves the soil vulnerable to excessive disturbance and erosion due to compaction, particularly by livestock. It is likely that the soil frost process has changed for glades (particularly the shallowest soils over slab rock) due to the excessive soil erosion that occurred during either the open range era or if the glade remains subject to grazing or other compaction.

Current Conditions and Threats:

Many factors associated with post-European settlement have negatively altered glade ecosystems and changed the conditions within which native plants and animals associated with glade systems adapted and evolved. While fire suppression is perhaps noted most frequently, other factors, including domestic livestock grazing, logging, conversion to fescue and exotic species invasion, land development, and fragmentation have influenced glade vegetation. These post-settlement disturbances have had damaging effects on fragile glade soil profiles and plant and animal species. These combined impacts also foster a trend toward biotic homogenization, which results in the gradual replacement of ecologically distinct natural communities by those dominated by weedy generalists (McKinney and Lockwood 1999).

Threats to glade systems are ongoing, however. Many glades continue to be grazed, and exotic species continue to proliferate and invade. Newer threats, such as quarrying, root-digging, plant and animal collecting, removal of large rocks for landscaping, and especially urban development are on the increase across the assessment region. Glades often are plowed for fire breaks, used as logging decks, or converted to food plots. The degree to which a glade is stripped of its original grass/forb matrix often can be attributed to soil disturbance, erosion, or loss due to the effects of historic or present overgrazing or poor grazing practices (Paul Nelson, personal communication).

Describing high-quality glade associations

Efforts to conserve the biodiversity specific to glade ecosystems entail managing and protecting an array of sites that can assure the viability of the endemic and obligate plant and animal species associated with them. It is necessary to understand the components of the glade ecosystem that can be used to assess and rank the quality of extant glades and glades complexes in order to prioritize conservation efforts. Techniques and approaches need to be formalized and adopted to allow ecologists to identify high-quality reference sites for the various glade associations and to better understand the ecological processes under which they operate.

The identification of "conservative" plant species as a tool for identifying high-quality glades has been proposed by Wilhelm and Ladd (1988), Swink and Wilhelm (1994), and Nelson (2010). Conservative plant species are defined as those that have a high affinity for undisturbed natural sites or landscapes. A conservative species reflects the degree to which the plant is faithful to a narrow range of ecological conditions and sensitive to degradation associated with post-European settlement. Healthy or high-quality natural communities are generally characterized by an abundance of grasses, sedges and forbs representing many plant genera and families associated with a stable or near "climax" community. This species richness is likely due to the gradual accrual of plants and animals associated with ancient, highly developed soil profiles, even on glades. The use of conservative species as a tool for identifying high-quality glades has been put into practice in Missouri by The Nature Conservancy, Missouri Department of Conservation, and the Mark Twain National Forest. In their glade assessment for Missouri, for example, Ladd and Heumann (2006) ranked desirable glade quality conditions based on the number of conservative species (up to 40), the presence of a rich forb mix in an intact perennial grass mix, the relative absence of invasive exotic species, the presence of diverse lichens, and the combined most diverse and equitable distribution of conservative forbs. The use of conservative species also is gaining favor with ecologists and managers in other parts of this assessment region (See the Ecological Assessment Database website: http://assessmentmethods.nbii.gov/index.jsp?page=mdetail&mid=38 for the states in the glade assessment region using some form of this floristic quality methodology.)

Plant and Animal Species of Conservation Concern:

The U.S. Forest Service sensitive species framework specifies that Forest Plans and regulations must provide for sufficient fish and wildlife habitat (ecosystems and natural communities) to maintain viable populations of existing native plants, fish, and wildlife species. The Forest Service Manual (FSM 2670.15) defines sensitive species as "those plant and animal species identified by a Regional Forester for which population viability is a concern as evidenced by significant current or predicted downward trend in numbers and density" and "habitat capability that would reduce a species existing distribution."

For the Forest Service, a conservation assessment gathers the current state of knowledge for Regional Forest Sensitive Species (RFSS) to aid in the development of conservation and recovery approaches. Sensitive species are identified by Regional Foresters to avoid trends toward federal listing and to maintain viability. However, this assessment is much broader in scope, including all species of conservation concern identified for the respective glade types listed in this assessment. For purposes of this assessment, viability is expanded to consider NatureServe's global ranks (G-ranks) and state ranks (S-ranks) that can address regional priorities and vulnerabilities.

The following explanation of conservation ranks is adopted from Tennessee Division of Natural Areas (2009) and NatureServe (2011):

As a guide to assessing the conservation status and risk of extinction or elimination for species and communities, NatureServe uses a ranking system for estimating species' and communities' abundance[1]. NatureServe Central staff assigns the global rank (G-rank) based on the best range-wide (global) abundance information for each element. A five-tier system (G1- G5) is used to describe rarity, from G1 (extremely rare) to G5 (widespread). The same system is applied by state and provincial heritage programs to assign the state rank (S-rank), which describes the elements' abundance within a state's borders.

Numerous land management agencies, including the U.S. Forest Service and National Park Service, use G-ranks to help determine sensitive species that occur on their properties. States possessing the legal authority to list species as rare (e.g., threatened or endangered) utilize S-ranks to determine the appropriate legal listing of a particular species within their borders. In addition, state natural heritage programs use both G-ranks and S-ranks of species and communities at a given site to prioritize site conservation.

S-ranks and G-ranks are based in part upon the number of occurrences of the element within the state and range-wide, respectively. For obscure or under-studied species, ranks are based on the best available information, and consideration may be given to other factors influencing the rarity of each taxon, including threats, abundance, population trends, and distribution.

Some S-ranks used within this document are defined in Table 2, below. G-ranks are similarly defined, except that ranking criteria apply range-wide (e.g., an S1 species is "critically imperiled" in the state, and a G1 species is "critically imperiled" range-wide).

Table 4. NatureServe State (S) rank Definitions.

S1	Extremely rare and **critically imperiled** in the state (often with five or fewer occurrences), or very few remaining individuals, or because of some special condition where the species is particularly vulnerable to extirpation
S2	Very rare and **imperiled** within the state, six to twenty occurrences, or few remaining individuals, or because of some factor(s) making it vulnerable to extirpation
S3	**Vulnerable**, rare, and uncommon in the state due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation
S4	Uncommon but not rare, and **apparently secure** within the state, but with cause for long-term concern due to declines or other factors
S5	Demonstrably common, widespread, and **secure** in the state
SH	Of **historical** occurrence within a state, e.g., formally part of the established biota, with the expectation that it may be rediscovered
SX	Believed **extirpated** from the state with little expectation of rediscovery

[1] Collectively all taxa and communities are referred to as "elements of conservation," or simply "elements."

S#S#	Denotes a “range rank” because the rarity of the species is uncertain (e.g., S1S3)

The master plant list (see Appendix 5).

The glade assessment team developed criteria for identifying and developing a master list for plant species that were strongly associated with glade habitat. The final list (see Appendix 5) includes 207 plants. Botanists and ecologists chose species that are state ranked and strongly dependent on glade habitat (and in some cases bordering woodlands). Species appear on the master list if the glade habitat preference was “obligate, optimal, or suitable.” These are defined as follows:

1. Obligate: The species primarily occurs on glades only; the glade habitat is essential to its survival. This includes many glade endemics. Nearly all known occurrences for the individual species are on glades.

2. Optimal: The species may occur in other habitat types but the glade is still the most favorable habitat. Most individual species occurrences are on glades. Glade habitat is still likely the primary habitat of conservation concern.

3. Suitable: The species occurs elsewhere to the extent that other habitat types may be primary or at least of equal conservation importance.

States also used the ranking “marginal” to mean that the species is best suited to other habitat types, although it might occasionally occur on glades. By displaying all the habitat preference rankings in Appendix 5, it is clear that glades across the geographical assessment area are the most important habitat type for most species. However, some states ranked glade habitat as marginal or suitable while others might have ranked glades as obligate or optimal.

Other important data provided in the master plant list includes the respective NatureServe identifier code, taxonomic treatment, standard common name (NatureServe), and the four digit number identifier code for the NatureServe glade type.

The development of this master plant list was essential in profiling the history, taxonomy, conservation status, threats, distribution, and existing or needed management/conservation actions for each species.

Glade Assessment Region:

The glade assessment region includes glade systems occurring in the Interior Highlands and Interior Low Plateau portions of the Central United States within the following ecological sections and subsections as delineated by Cleland et al. 2007 (Figs. 1 and 2.; Section and subsection names can be found in their respective sections, below.)

Figure 1. Glade assessment region showing ecological sections superimposed over Central Hardwoods Joint Venture geographical planning area.

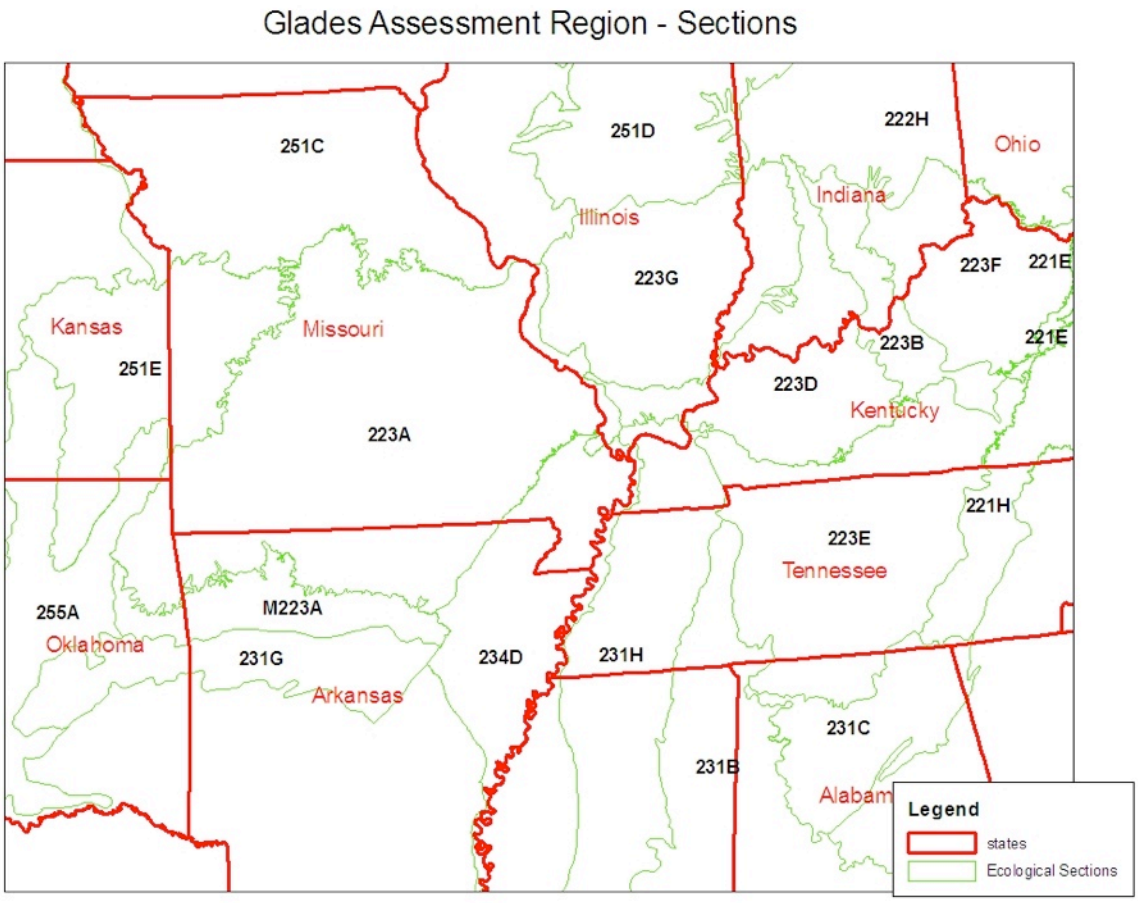
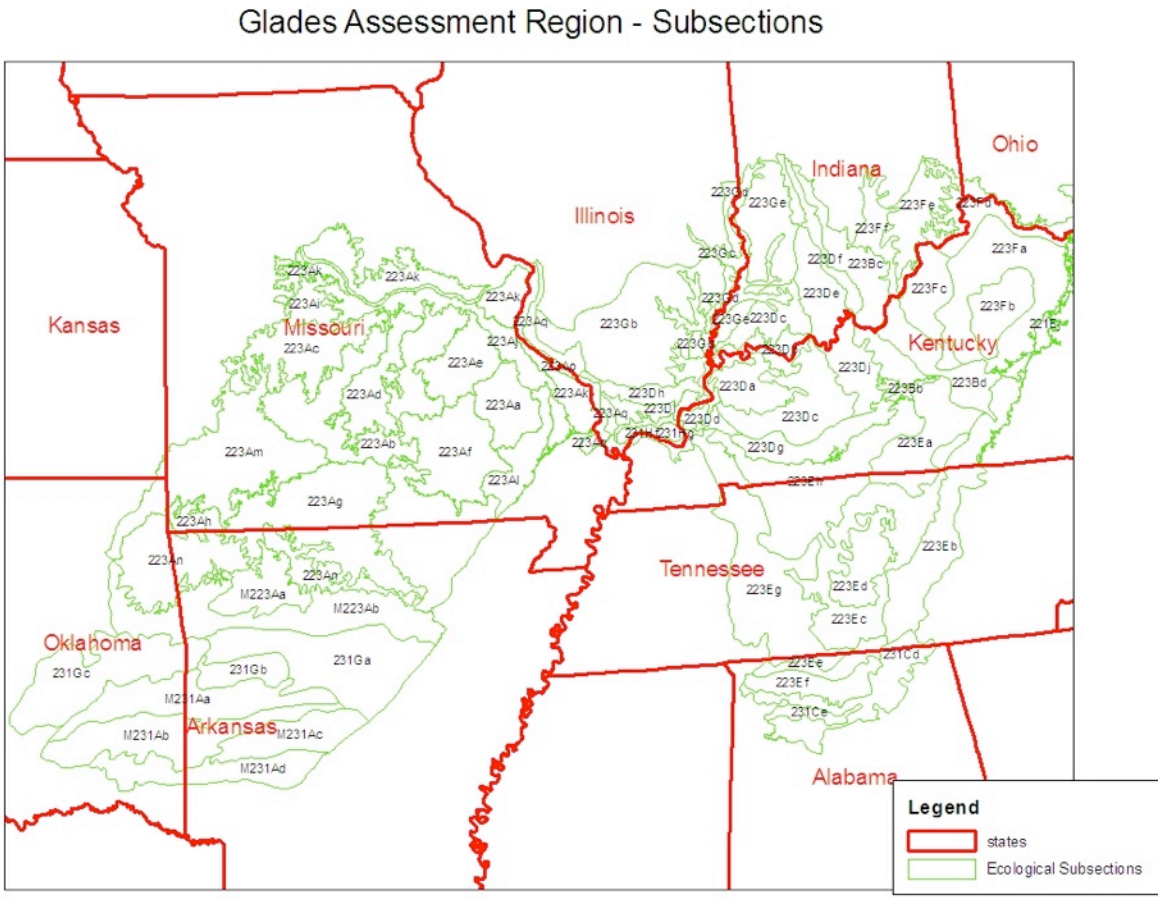


Figure 2. Glade assessment region showing ecological sections superimposed over Central Hardwoods Joint Venture geographical planning area.



Glade Types and Classification:

Ecological Subregions: Sections and Subsections of the Conterminous United States (Cleland et al. 2007) is the primary ecosystem framework for this assessment. This national framework provides a broader ecological context from which to uniformly identify ecological units at multiple spatial scales. This is coupled with NatureServe's ecological system and plant association classification. Various ecologists working on this assessment have provided new information resulting in the addition or modification of several glade associations.

At the natural community unit level, the assessment uses NatureServe's U.S. National Vegetation Classification System as the source for classifying and describing 24 named glade associations within 7 ecological systems found within the assessment region. The plant association is the primary habitat focus, both for conservation of healthy glade systems, and for their respective species of conservation concern. Jennings et al. (2009) describe the association as "a vegetation classification unit defined on the basis of a characteristic range of species composition, diagnostic species occurrence, habitat conditions, and physiognomy...despite a characteristic

range of species composition and diagnostic species, results vary continuously due to historical and environmental stochasticity." Ecological systems are a mid-scale classification unit representing recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding (Comer et al. 2003). Systems and associations referenced in this assessment are listed in Table 6, and searched online via http://www.natureserve.org/explorer (NatureServe 2011).

Table 5. Glade Classification Hierarchy, adopted and modified from Nigh and Schroeder (2002):

Scale	**Ecological Unit**	**Size**	**Reference**
Ecoregion	Province	10,000 sq. mi. (2,589,998 ha)	Avers et al. 1994
Subregion	Section	1000 sq. mi. (258,998 ha)	Avers et al. 1994
	Subsection	10-100s sq. mi. (2,590-25,899 ha)	Avers et al. 1994
Landscape	Landtype association	100s of ha to 10s km^2	List by state: Nigh and Schroeder 2002
Land Unit	Glade Association	Site .5-100s ha	NatureServe Plant Associations

Because any ecological classification system is dynamic, somewhat arbitrary, and evolving, experts working on this assessment in some states also recognize other glade-related variations that warrant inclusion in this assessment, as noted in the sections to follow. Table 6 shows the glade associations known within the glade assessment region.

Table 6. Glade associations known within the glade assessment region. (Source: NatureServe).

Association Name	**NatureServe Number**	ILL	IND	KEN	TENN	ARK	OKL	ALA	MO
Ozark Limestone Glade	CEGL002251					x			x
Ozark Dolomite Glade	CEGL002398					x			x
Ozark Annual Grass Glade	CEGL008563					x			
Outer Bluegrass Dolomite Glade	CEGL007772			x					
Ozark Ashe's Juniper Glade Woodland	CEGL007833					x	x		x
Quachita Basic Shale/ Sandstone Glade	CEGL007824					x	x		
Central Shale Glade	CEGL002428	x	x	x					
Ozark Sandstone Glade	CEGL002242					x	?		x

Ozark Basic Sandstone Glade	CEGL007814					x			
Shawnee Sandstone Glade	CEGL004062	x	x	x					
Ozark Igneous Glade	CEGL002243								x
Ozark Chert Glade	CEGL002244								x
Central Limestone Glade	CEGL005131	x	x	x	x			x	
Southern Limestone Glade Margin Shrubland	CEGL003938			x	x			x	?
Limestone Annual Grass Glade	CEGL004340			x	x				
Kentucky Glade Seep	CEGL004669			x					
Interior Low Plateau Limestone Glade Ephemeral Pool	CEGL004346			x	x				
Mouton and Tennessee Valley Limestone Hill Barrens	CEGL004738				x			x	
Tiak Limestone Glade	CEGL007812					x	x		
Quachita Novaculite Glade	CEGL007825					x	x		
Nepheline Syenite Herbaceous Glade	CEGL008421					x			
Nepheline Syenite Wooded Herbaceous Glade	CEGL008422					x			
Limestone Seep Glade	CEGL004169				x	x		x	x
Limestone Glade Streamside Meadow	CEGL004292				x			x	

Glade Distribution and Sensitive Species by Ecological Subsection:

The following sections describe each ecological section and subsection in this assessment in detail, including the size, location, and characteristics of each one. The sensitive species in each subsection are listed, along with glade threats, management issues, and State, Federal, non-profit organization and private protection status.

Ozark Highlands Ecological Section 223A
12,300,713 ha total in Missouri and Arkansas

This distinctive biogeographic region of southern Missouri and much of northern Arkansas is a low structural dome of variably aged rock strata with the dome center consisting of the oldest (1.5 billion yr) igneous rock in the St. Francois Mountains (Nigh 2002). A quarter billion years of exceptional geologic erosion, wind transport, and subterranean karst dissolution has created a diversity of landforms that vary in degree of relief, dissection, and geologic parent materials. This ancient landscape and its physiographic diversity have created a region of unique ecosystems, especially glades. Differences in landform, soils, and vegetation produce 18 ecological subsections in the Ozark Highlands of Missouri and Arkansas. The presence of major river drainage systems down-cutting through that portion of the Ozark dome containing a particular rock type results in some subsections having high occurrences of distinctive glade types and distribution. For example, the Jefferson City-Cotter dolomite rock formation and igneous domes of the St. Francois Mountains are major glade producers. Further, this ancient historic presence of glades has resulted in the accrual of a glade-endemic association of plant and animal species.

The Ozark Highlands occur in the western half of the Humid Temperate Domain (Bailey 1995). This determines its overall climate regime of four seasons with strong annual cycles of precipitation and temperatures. Summers are relatively hot while winters range from mild to bitterly cold. Unlike the ecological sections occurring further east and south in the assessment area, the Ozark Highlands is subject to extended dry periods creating extreme drought conditions. Such conditions stress the otherwise woody invasion that accompanies fire-starved and degraded glade locations in a subhumid to humid climatic setting. Tree diebacks are documented across the excessively drained shallow bedrock glades (and dry woodlands) of Missouri and northwest Arkansas.

Nigh and Schroeder (2002) and Foti and Bukenhofer (1998) provide an in-depth description of the ecological units covering the Ozark Highlands. Their guide follows standard formats for describing section and subsection units, including location, boundaries, climate, topography, geology, soils, hydrology, and major natural community types. All of these described parameters in part help to explain the occurrence of the glade associations known from the Ozark Highlands

Missouri and Arkansas glades are thought to be fire-mediated natural communities in the Ozark Highlands, perhaps excepting the most exposed, shallow soil glades of cliff tops. Guyette and McGinnes (1982) estimated the mean fire frequency from tree-ring studies to be 1 fire in every 3.2 yr from the period 1730 to 1870 for glades in the White River Hills Subsection. Farther east, fire was estimated at 1 fire every 4.3 yr from 1700 to 1810 (Guyette 1989). Woody vegetation (especially red cedar) encroaches upon or invades nearly all glade types in the absence of either fire and/or thinning. Fire regimes vary among glade regions of the Ozark Highlands as dictated by topography, the presence of streams and rivers, and locations for anthropogenic ignition

sources. Fire management is described in detail in Nelson 2010 (Ecosystem Management chapter by McCarty).

Glade Descriptions (area, type, flora)

Nelson (2010) characterizes 4 glade types in *The Terrestrial Natural Communities of Missouri*, which then became the basis for describing the NatureServe glade associations below (Table 7).

Table 7. Comparison of Nelson's Missouri glade natural communities and those described in NatureServe.

Nelson 2010	**NatureServe**	
Limestone Glade	Ozark Limestone Glade	CEGL002251
	Limestone Seep Glade	CEGL004169
	Limestone Glade Ephemeral Pool	CEGL004346
Dolomite Glade	Ozark Dolomite Glade	CEGL002398
	Ozark Ashe's Juniper Glade Woodland	CEGL007833
Chert Glade	Ozark Chert Glade	CEGL002244
	Ozark Sandstone Glade	CEGL002242
Igneous Glade	Ozark Igneous Glade	CEGL002243

Ozark Highland glades occur on igneous, sandstone, limestone, dolomite, and chert bedrock with a high resistance to weathering. Soil depth is very shallow, ranging from 0 to (rarely) 50cm deep and interspersed with copious rock fragments and outcrops. Steep slopes, active erosion, and resistant bedrock maintain shallow soils, but in some sites, thin soils and exposed pavement-like bedrock occur on flat terrain. High temperatures, intense solar radiation, and dry conditions prevail throughout much of the growing season, although soils may be saturated in spring, winter, and fall. Frost upheaval frequently disrupts these shallow soils during the dormant season.

Ozark igneous, sandstone, and chert glades support many vascular plants, mosses, and lichens that exhibit a fidelity to acid substrates, while limestone and dolomite substrates support species allied to alkaline (or neutral) conditions (Steyermark 1963, Nelson 2010). Nelson listed the dominant, characteristic, and restricted glade plant species for the five major glade types based on rock substrate. Nelson and Ladd (1983) listed over 400 vascular plant species sorted by glade type. Ver Hoef et al. (1993) documented a total of 365 vascular plant species on 3 substrate types (igneous, sandstone, and dolomite) in the Ozark National Scenic Riverways. Palmer (1910) and

Steyermark (1963) documented chert glade flora. Redfearn (1983) collected 74 species of mosses from glades in southwestern Missouri.

Limestone Seep Glades and Limestone Glade Ephemeral Pools are described in NatureServe as occurring as zonal components of Central Basin (Tennessee) and Moulton Valley (Alabama) Limestone Cedar Glades. These types are referenced here because these zonal components are quite common on almost any large dolomite or limestone glade in the Ozark Highlands. Plant species occurring in the seep zone are described as "gravelly marly zones" in Nelson (2010). Fen-like calcareous seeps also often occur in association with dolomite glades, but are not glades because their characteristic species are those found in larger Ozark fens. Rather than separate out these "inseparable" zonal components, they are considered characteristic features found within most limestone and dolomite glades in the Ozark Highlands.

The "delicate and fragile" carpets of lichens and mosses (Steyermark 1963) that occur on shallow soils of igneous and sandstone glades are now believed to be artifacts of severe overgrazing and loss of perennial grasses and forbs.

Sensitive Species

Glade Animals

A few Missouri animals are well adapted to living on glades. The plants and animals associated with glades are able to survive through avoidance or tolerance of intense radiation, high temperatures, and soil moisture deficits. Many of the animal species observed on glades are ecotonal (transitional between natural communities) species of woodland-grassland borders while others are habitat generalists (Sexton 1982). These casual visitors from the adjacent woodlands use glades but are not necessarily well adapted to living in the parched, desertlike habitat.

Three factors affect the dynamics of glades and thus the abundance and diversity of the faunal species (Sexton 1982); extremely dry conditions, solar qualities, and the types of available energy and nutrients. The extremely dry, desertlike condition of glades has attracted animals with their primary distribution in the more arid southwestern United States. The eastern collared lizard (*Crotaphytus collaris collaris*) and greater roadrunner (*Geococcyx californianus*) persist from an earlier xerothermic period on some of the larger Missouri glades (Bergmann 1983). Sexton (1982) found reptiles to be the dominant vertebrate fauna on eastern Missouri glades. He considered the following reptiles to have primary distribution centers on glades; flat-headed snake (*Tantilla gracilis*), eastern coachwhip (*Masticophis flagellum flagellum*) and eastern collared lizard. In Missouri, the eastern collard lizard is generally restricted to glades, especially large dolomite, sandstone, and igneous glades. Other glade-associated amphibians and reptiles include the eastern narrow-mouthed toad (*Gastrophyne carolinensis*), southern coal skink (*Eumeces anthracinus pluvialis*), six-lined racerunner (*Cnemidophorus sexlineatus*), prairie racerunner (*Cnemidophorus sexlineatus viridis*), Great Plains rat snake (*Elaphe guttata emoryi*),

red milk snake (*Lampropeltis triangulum syspila*), ground snake (*Snora semiannulata*), and western pygmy rattlesnake (*Sistrurus miliarius streckeri*).

Glades provide valuable habitat for priority or watch-listed bird species of the Ozark Highlands Section, including the field sparrow (*Spizella pusilla*), brown thrasher (*Toxostoma rufum*), and painted bunting (*Passerina ciris*, Jacobs 2001). The greater roadrunner (*Geococcyx californicus**) is the only bird largely restricted to the dolomite glades in southwestern Missouri. Bachman's sparrow (*Aimophila aestivalis*) is often found on dolomite glades, but it can also be found in open pine-oak woodlands (Jacobs 2001). Roadrunners have slowly increased in Missouri, while Bachman's sparrow has declined. Bird watchers have sighted several other bird species of glades in other natural communities, particularly surrounding woodlands. These species include the common nighthawk (*Chordeiles minor*), which historically nested on glades, Chuck's will-widow (*Caprimulgus carolinensis*), prairie warbler (*Dendroica discolor*), and painted bunting (*Passerina ciris*).

The Texas mouse (*Peromyscus attwateri*) is the only mammal restricted to glades in Missouri. This southwestern ranging desert mouse is found in the southwest portion of Missouri, where it occurs on dolomite glades of the White River Hills Subsection. Several other species of mammals such as eastern woodrat (*Neotoma floridana*) and deer mouse (*Peromyscus*) species can be found on glades; however these species also use many other types of habitat. Their attraction to the glades may be primarily due to the glades' rocky structure and open canopy--features also found in other natural communities.

Entomologists have conducted few studies focused specifically on glade invertebrate groups. Orthopterans (grasshoppers, katydids, and crickets), arachnids (harvestmen, spiders, and scorpions), and Lepidoptera (butterflies and moths) are probably the best studied. The lichen grasshopper (*Trimerotropis saxatilis*) is one of the few grasshoppers restricted to glade habitat in the Ozarks (Bergmann 1983). Gerber and Templeton (1996) speculated that the presence of lichen grasshoppers was closely tied to the ecological quality of the glade. They found that populations of this grasshopper increased when managers improved glade quality through prescribed burning and tree thinning. In their survey of Missouri's orthopterans, Ballard and Greenlee (1996) found the rare immodest grasshopper (*Melanoplus impudicus*) only on glades, the boopee grasshopper (*Boopedon auriventris*) often on glades (also sometimes on dry-mesic prairies), and Say's grasshopper (*Spharagemon equale*) on chert glades. Saussure's grasshopper (*Pardalophora saussurei*) is very rare, occurring on Missouri glades. The Texas brown tarantula (*Aphonopelma hentzi*), black widow spider (*Latrodectus mactans*), and striped bark scorpion (*Centruroides vittatus*) are strongly associated with glades. Missouri has one butterfly, the Ozark swallowtail (*Papilio joanae*) that is primarily restricted to Ozark glades. Several other glade-associated Lepidoptera include the dusted skipper (*Atrytonopsis hianna*), cobweb skipper (*Hesperia metea*), a pyralid moth (*Melitara prodenialis*), and pepper and salt skipper (*Amblyscirtes hegon*). The largest tiger beetle (*Cicindela vulturina*) in the state is restricted to dolomite glades in the White River Hills Subsection.

Several glade-associated ants (personal communication, Dr. James Trager, Missouri Botanical Gardens) include (no common names): Subfamily Myrmicinae: *Crematogaster lineolata*, *Monomorium minimum*, *Pheidole tysoni* (sandstone glades); Subfamily Dolichoderinae: *Forelius pruinosus*; and Subfamily Formicinae: *Formica schaufussi* (acid substrates) and *Paratrechnia terricola*. Highly glade-associated bees include (no common names): Family Colletidae: *Colletes aestivalis*; Family Andrenidae: *Andrena helianthiformis*, *Protandrena rudbeckiae*; Family Halictidae: *Lasioglossum coreopsis*; and Family Megachilidae: *Anthidium psoraleae* and *Dianthidium subrufulum* (restricted to glades).

The presence of glade restricted animals, particularly insects, presents a management challenge, especially when using prescribed burning. The use of fire presents a conundrum in that although conditions existed prior to European settlement for insect populations to remain viable in a fire-mediated landscape, today's intensively altered landscape conditions may impose greater stress on certain plant and animal populations when using fire in contemporary confined landscape or local area restoration sites.

While other states have not provided extensive information regarding animals associated with glades, the study of glades animals in Missouri indicates that other glades likely support populations or associations of animals, particularly invertebrates, adapted to and confined to glade habitat.

Disturbance Regimes

Understanding the disturbance regimes by which plant and animal species evolved and adapted over thousands of years is critical to the restoration and maintenance of quality glade habitat for the 45 species of conservation concern found in glade associations of the Ozark Highlands. Through the understanding of disturbance regimes, managers exert the range of control that achieves management objectives. Disturbance regimes have six main elements: frequency, duration, intensity, extent, pattern, and seasonal timing. Each element is a variable which to some extent may be changed or altered independent of others (McCarty; in Nelson 2010). A characteristic range exists for each disturbance, with both averages and extremes being significant in shaping the character and composition of glade associations. The range of natural variability for each is a function of the physical environment, geology, and landform, and the interaction with other physical/biological features. These are likely similar across the ecological systems (described in NatureServe) under which the respective subsets of glade associations developed.

Fire, drought, frost upheaval, and native grazers were the primary natural disturbances on glades. Historically, their dominance by grasses, sedges, and forbs depended on frequent fire. Guyette and McGinnes (1982) estimated the mean fire frequency from tree ring studies to be one fire in every 3.2 yr from the period 1730 to 1870 for glades in the White River Hills Subsection. Farther east, fire was estimated at one fire every 4.3 yr from 1700 to 1810 (Guyette 1989).

Glades are thought to be fire-mediated natural communities in the Ozark Highlands, perhaps excepting the most exposed, shallow soil glades of cliff tops. Woody vegetation (especially red cedar) encroaches on nearly all glade types in the absence of either fire and/or thinning the red cedar. Fire regimes vary among glade regions of the Ozark Highlands as dictated by topography, the presence of streams and rivers, and locations for anthropogenic ignition sources. Fire management is described in detail in Nelson 2010 (Ecosystem Management chapter by McCarty).

Threats to Glades of the Ozark Highlands

Overgrazing

The majority of Missouri's estimated 81,000 ha of glades are substantially degraded (Nelson and Ladd 1983; Missouri Natural Heritage Database; Smith 1990). Decades of overgrazing have eroded the shallow, fragile, original soil layer from glades (Hammer 1996, Erickson et al. 1942). This overgrazing has decreased the number and diversity of species and has caused changes in the distribution of opportunistic and conservative glade species. Guyette and McGinnes (1982) postulated that the dominance of red cedar on most dolomite glades in the White River Hills Subsection resulted from the combination of open-range overgrazing during and after the time of settlement followed by fire cessation. Red cedar dominance increases with grazing and the species readily invades limestone or dolomite glades (and degraded woodlands). Ladd and Heumann (2006) surveyed 29, 81-ha glades on the Ava Ranger District of the Mark Twain National Forest. Of these 29 glades, 5 were ranked as good quality, 16 as moderate quality and 8 as poor quality. Regarding their assessment, they noted "There is a negative association between glade quality and recent grazing patterns, especially dormant season grazing activity. The highest quality glades tend to occur in portions of the region with an extended history of grazing deferral or recent history of only light grazing." Smith (1990) examined a total of 502 potential natural feature sites located in 4 counties that include extensive glade complexes. His inventory concludes that many glades in his four-county study area did not qualify as natural areas due to the history of overgrazing. He further notes "Open glades were invaded by cedars and other woody species or were overgrazed to the point that native species composition was compromised."

Often, sites were seriously overgrazed and suffered extensive erosion. In addition, these non-native plants frequently escape and move into adjacent habitat, rendering it useless as well. Grazing animals also reduce the quality of glade and barrens habitats through soil compaction and the selective removal of plant species essential to the survival of glade and barrens insects.

In the absence of fire and drought, physical barriers created by the encroachment of woody species restrict the movement of glade animals between glade openings, resulting in genetically

isolated populations. Templeton et al. (2001) documented these barriers for eastern collared lizards (*Crotaphytus collaris collaris*) in Stegall Mountain Natural Area in Carter County.

Exotic Species Invasion

Exotic species, including sericea lespedeza (*Lespedeza cuneata*), yellow sweet clover (*Melilotus officinale*), spotted knapweed (*Centaurea maculosa*), common teasel (*Dipsacus fullonum*), crown vetch (*Securigera varia*), cheat and brome grasses (*Bromus tectorum*, *B. sterilis*, *B. hordeaceus*, *B. japonicas,* and *B. racemosa*), plume grass (*Miscanthus sinensis*), meadow fescue (*Festuca pratensis*), and tall fescue (*F. arundinacea*) threaten Ozark glade communities. Highway right-of-way plantings, including sericea lespedeza and crown vetch, provide extremely effective vectors for distributing and expanding these serious invaders. For example, nearly every road right-of-way throughout southern and central Missouri now harbors sericea lespedeza. Domestic livestock and other wildlife also serve as vectors for the spread of exotic species into degraded and weakened natural communities.

Urbanization, Development, and Rock Quarrying

Certain glade regions also occur near urban areas, man-made lake reservoirs, and atop bluffs along rivers that are attractive for home construction. Homebuilders and developers often prefer ridge tops above or on glades for the panoramic views they provide. Historically, the presence of a glade signaled the presence of rock material suitable for quarry operations.

Collecting Plant, Animal, and Native Field Stone from Gades

Illegal digging of glade plants and collection of animals is also resulting in the degradation of high-quality glades. Pet shop owners or individual reptile collectors use pry bars to turn over large boulders and ledge rock to collect attractive snakes and lizards. Digging in glades steadily exposes fragile, thin, organic soil, eventually eroding it away and leaving behind more acid gravel and rock debris. Plant species diversity and cover are diminished as a result, and recovery is slow because of drought conditions.

Resort developers and homeowners find field stone that is naturally weathered and covered in lichens attractive for use in constructing indoor fireplaces or landscaping walls. Many building suppliers sell field stone. This removes vast quantities of stone that is critical habitat for a wide variety of glade-inhabiting animal species.

Illegal or Inappropriate Trespass on Glades

Illegal recreational activities also jeopardize the integrity of glade habitats. Unauthorized horseback riding, mountain biking, and off-road vehicles create unsanctioned trails, resulting in accelerated erosion, the destruction of threatened or conservative plants, and other damaging effects. For example, in Missouri, ATV users find expansive, open, rocky glade habitat

challenging and desirable for ATV use. Hundreds of km of highly eroded ATV trails dissect glades and adjacent open woodlands both on private and public lands.

Unknown Effects of Prescribed Fire or Lack of Fire on Insects

Little is known about the effects of either prescribed burning or lack of fire on glade insect species. There is little documentation of these effects for glades but greater documentation for other fire-mediated natural communities, including prairies and barrens (Olson 2002).

Animal Overpopulation

White-tailed deer populations pose a serious threat to many ecosystems throughout the eastern United States (Curtis and Sullivan 2001). High deer populations can alter the entire vegetation succession pathway for forests and woodlands, affecting tree regeneration and reducing species richness. Plant species diversity and individual species can be reduced or entirely eliminated (Rooney 2003; Rooney et al. 2004), and aid in the increase of invasive species such as Japanese stiltgrass (*Microstegium vimineum*).

Feral hog numbers are dramatically increasing across the Arkansas and Missouri Ozark Highlands. Hogs dig and overturn extensive vegetation mats on glade bedrock looking for insects, reptiles, small mammals, and plant roots. This results in extensive soil erosion and loss of plant/animal species diversity. Feral hog damage to glades is documented at Taum Sauk Mountain State Park (Nelson 2010), Butler Hollow Glade Natural Area, and across the glades on the Ava Ranger District of the Mark Twain National Forest (radio telemetry conducted by the Missouri Department of Conservation).

Inventory, Monitoring, and Research

The primary purpose of monitoring is to ensure that ecosystem restoration activities are effective in meeting desired conditions and in preserving plant and animal populations of concern. For purposes of restoring glade natural communities we define monitoring as the collection and analysis of repeated observations to evaluate changes (good or bad effects) in conditions and progress toward meeting management objectives. A primary monitoring method is measuring trends in species richness, to emphasize whether management actions favor restoration treatments to restore the viability of plant and animal populations connected with high quality pre-European natural communities.

Inventory

Beginning in 2010, The Mark Twain National Forest initiated GIS spatial glade distribution mapping for the White River Hills Subsection and National Forest lands. Resolution is high. The methodology includes interpretation of soils, geology, leaf-off .6-m aerial photography, infrared leaf-on satellite images, and historic GLO tree data. While mapping is done with a computer,

results are field tested for glade delineation and glade type and are highly accurate. Mapping is complete for the White River Hills, St. Francois Knobs and Basins, and all the Ozark Chert Glade area in the Springfield Plateau Subsection. This mapping process continues. General results are quantified in the ecological subsection narratives.

Monitoring and Research

- Mapping glades
- Reference locations
- Vegetation change
- Population status and viability
- Floristic richness
- Bird studies
- Need for quantifying insect populations

The Mark Twain National Forest, The Missouri Department of Conservation, Missouri Department of Natural Resources, The Nature Conservancy, Ozark National Scenic Riverways and other organizations have been using the Floristic Quality Assessment methodology of evaluation for over 15 yr in Missouri, resulting in over 100 monitoring project studies and reports, many from glade sites. The Floristic Quality Index (Taft et al.1997) is expressed as an index based on numerical values (0 to 10) assigned to each native vascular plant species. This numerical index is an expression of the relative integrity of the ecosystem, much like the optimal range of numerical indices established for cholesterol or blood pressure measurements in humans. Additionally, the actual values assigned to plant species reflect the relative degree to which the species and collection of species are restricted to high-quality ecosystems. The presence of plant species assigned values greater than 5 often indicate good quality, least disturbed habitats. Likewise, species assigned values less than 5 often indicate poor quality habitats (old fields, lawns, overgrazed woodlands). For meeting the goals and objectives of sustaining high quality glades (and other natural communities) the aggregate mean floristic quality index of the area's flora is an effective predictor of site potential for ecosystem recovery or achieving desired conditions for plant species richness. Plot data from vegetation sampling serves as an effective means of assessing current conditions, because numerical values and indices will reflect the degree to which conservative plant species are distributed (as well as species at risk) within a given area.

The Floristic Quality Index is based on repeated sampling of vegetation in randomized plots (typically 50, 1/4-square-meter quadrats) along permanent line transects. These transects are located in representative natural communities for which information on biotic trends and changes, particularly in relation to ongoing management activities, is needed. In some cases these data are augmented with supplementary sampling of larger plots to derive tree data relating to structure, composition, and recruitment, or faunistic data such as breeding bird surveys. The rationale for this monitoring approach is explained in Heumann (2002).

The Mark Twain National Forest has established 75 and 36 permanent plots at Ava and Cassville glades, respectively, beginning in 2006. Floristic quality data was collected in 2006 and 2011.

St. Francois Knobs and Basins Subsection (223Aa)

The St. Francois Knobs and Basins subsection is distinctive due to the presence of Precambrian age bedrock resulting from ancient volcanic activity. It contains 10,582 mapped igneous glades totaling 4,176 ha. The largest igneous glade is 27 ha, while the mean is .40 ha. The subsection lies at the structural center of the Ozark dome commonly known as the St. Francois Mountains. Taum Sauk Mountain, the highest point in Missouri at 540 m (1,772 feet), occurs here. Many types of igneous intrusive and extrusive rock types make up a wide variety of Precambrian volcanic rock formations including various granites, syenite, diorite, rhyolite, ash-flow tuft, lava flows, and basalts. No one has attempted to study whether vegetation occurring on these different igneous glade formations is distinctive and warrants separate classification. No study yet suggests that floristic distinctions may occur among them, and despite being continuously available for plant occupation for many thousands of years, no truly endemic vascular plant species occurs on igneous glades in Missouri.

Dolomite glades also occur in the St. Francois Mountains where sedimentary rock formations occupy lower elevations surrounding igneous domes. These dolomite glades are relatively small (less than 2 ha) and occur on the Potosi, Derby-Doerun, Davis and Eminence geologic formations.

The federally threatened Mead's milkweed (*Asclepias meadii*) occurs on igneous glades in the St. Francois Knobs and Basins Subsection. Some of the populations of this milkweed exhibit broad genetic variability, making them valuable sources of propagules for reintroduction on igneous substrates (Bowles et al. 1995). Whitlow grass (*Draba aprica*) (RFSS) is another species of conservation concern.

Threats to glades include red cedar invasion, historical overgrazing damage, and removal of intact grass/forb cover, reducing species richness, digging of Mead's milksweed by feral hogs, and fire suppression. Winged sumac (*Rhus copallina*) and red cedar dramatically increased on igneous glades in the St. Francois Mountains following overgrazing and fire suppression (Ver Hoef et al. 1993). The Animal and Plant Health Inspection Service (APHIS), Department of Natural Resources (DNR), United States Forest Service (USFS), and Missouri Department of Conservation (MDC) of the Feral Hog Taskforce have removed over 500 feral hogs from the 2,833-ha St. Francois Mountains Landscape Natural Area that includes many igneous glades harboring Mead's milkweed populations.

Central Plateau Subsection (223Ab)
Missouri: 1,799,977 ha
Arkansas: 649,239 ha

The Missouri portion of this subsection contains a limited number of glades, particularly Roubidoux sandstone slabs along drainages where streams down cut through the Roubidoux formation. The Arkansas portion of this subsection includes some extensive dolomite glades of the Cotter, Jefferson City, and Powell formations with the largest individual glades exceeding 405 ha. It is the only subsection in Missouri with records of Bush's skullcap (*Scutellaria bushii*) (RFSS), celestial lily (*Nemastylis geminiflora*), Gattinger's prairie-clover (*Dalea gattingeri*), and limestone fameflower (*Talinum calcaricum*). Glades in this subsection in Arkansas also support populations of the federally Threatened Missouri bladderpod (*Lesquerella filiformis*). The southern end of this subsection in Arkansas includes many sandstone glades of the St. Peter Formation, some of which are extensive.

Protected areas with glades within this subsection in Arkansas include Rock Creek Natural Area, the surrounding Harold Alexander Wildlife Management Area, and The Nature Conservancy's Strawberry River Preserve. Restoration activities, including cedar removal and prescribed burning, are ongoing at Rock Creek Natural Area and the Harold Alexander Wildlife Management Area and are being funded by State Wildlife Grants.

Osage River Hills Subsection (223Ac)
Missouri: 717,779 ha

This subsection is composed of hilly to rugged lands associated with the Osage River drainage. From west to east the Osage River cuts through the Burlington Formation, where it forms large limestone and some sandstone glades, then dissects cherty dolomites and sandstones eastward near the Lake of the Ozarks. Extensive dolomite glades of the Gasconade Formation occur on the dissected hills surrounding the immediate shoreline and drainages of Lake of the Ozarks. These glades likely exceed 5,000 ac, with some glades as large as 50 ac. Western wallflower (*Erysimum capitatum*) occurs here along with other limestone-loving plant species, including few flower stickleaf (*Mentzelia oligosperma*) and limestone adders tongue (*Ophioglossum engelmannii*).

Gasconade River Hills Subsection (223Ad)
Missouri: 481,860 ha

This subsection lies in the northern flank of the Ozark uplift. Underlain by thick cherty dolomites and sandstones of the Gasconade and Roubidoux Formations, it forms both dolomite and

sandstone glades. Significant sandstone glades occur on the Houston/Rolla Ranger District along the Big Piney and Little Piney rivers. An estimated 1,214 ha of glades occur in this subsection.

Meramec River Hills Subsection (223Ae)
Missouri: 457,154 ha

This subsection consists of the hilly rugged woodlands of the Meramec River basin. Glades form on the thick cherty dolomites of the Gasconade Eminence Potosi Formation and sandstones of the Ordovician Gasconade. Wavyleaf purple coneflower (*Echinacea simulata*) (RFSS) occurs on dolomite glades in this portion of the Ozark Highlands. There is an estimated 1,214 ha of glades.

Current River Hills Subsection (223Af)

Missouri: 808,102 ha

This subsection contains the deepest dissected hills of the Missouri Ozark Highlands. The Current, Jacks Fork, and Eleven Point river valleys occur here. The subsection lies on the south flank of the Ozark uplift with a portion of the subsection containing exhumed Precambrian igneous knobs. Dolomite glades occur on Cambrian and Ordovician dolomites, generally on steep southwest facing ridges along rivers. Igneous glades and barren rock outcrops occur on all igneous domes. An estimated 2,428 ha of igneous and dolomite glades occur in this subsection.

White River Hills Subsection (223Ag)
Missouri: 878,832 ha
Arkansas: 573,390 ha

Ozark Dolomite Glades (CEGL002398) in Missouri and Arkansas comprise the most extensive glade distribution and area in the Ozark Highlands Section. In Missouri alone, the Mark Twain National Forest has mapped over 30,000 individual dolomite glades totaling 50,181 ha. Some of these glades are 567 ha. Of this total, approximately 13,355 ha occur on the Ava Cassville Willow Springs Ranger District of the Mark Twain National Forest. These glades have received much attention in botanical studies (Kucera and Martin 1957, Steyermark 1940 and 1963, Hicks 1981, Redfearn 1983, Nelson and Ladd 1983, Baskin and Baskin 2007). Their floral assemblage is distinct and contains several southwestern species at the eastern edge of their range. Trelease's delphinium (*Delphinium treleasei*) (RFSS), yellow coneflower (*Echinacea paradoxa* var. *paradoxa*) (RFSS), Missouri bladderpod (*Physaria filiformis*), Nuttall's pleatleaf (*Nemastylis nuttallii*), and Bush's skullcap (*Scutellaria bushii*) (RFSS) are endemic glade plants of the Interior Highlands (Yatskievych 1999). Many other plant and animal species of conservation concern also occur here.

James Harlan, Geographic Resources Center for the University of Missouri, spatially analyzed over 400,000 historic land survey trees from GLO notes collected in the early 1800s from the

glade region. This analysis concluded that very few red cedar trees were noted on the glades. Fire studies by Richard Guyette (Guyette and McGinnes 1982) concluded that red cedar (among other woody species) dramatically increased following overgrazing and fire cessation. Ladd and Heumann (2006) conducted a detailed rapid ecological assessment of the Ava Ranger District on the Mark Twain National Forest. Their report states that red cedar comprised less than 1% of historic witness trees recorded on the 11,736 ha of open glades within their assessment area. Thus, calling Ozark Highland glades "cedar glades" is misapplied in the historical ecological context, as red cedar is for the most part an artifact of overgrazing and fire suppression in this subsection (Martin and Crosby 1955). It has allelopathic effects that may prevent desirable plants from entering areas (Quarterman 1973). Red cedar can create 100% canopy cover on glades, and once it attains an age of 60-80 yr, fire alone is ineffective in removing it. Many of the remaining native grasses, sedges, and herbs are often suppressed to irreversible recovery thresholds, and may not be available for recolonization through restoration activities. Kimmel and Probasco (1980) used aerial photography to document the rate at which red cedar was covering open grass-forb dominated glades at sites on the Mark Twain National Forest. They showed a decline in the size of glade openings from 50 % in 1938 to only 16 % in 1975. Janet Hicks (1981) in her Vegetative Analysis of Hercules Glades Wilderness master's thesis also documented the steady progression of glade closure due to red cedar invasion due to historical open range overgrazing and fire suppression.

High fire frequencies, which resulted from rapid fine fuel build-up before the introduction of domestic livestock, kept glade vegetation open and prevented the invasion of woody species. In addition, annual grasses and forbs commonly occupy glades when grazing and soil loss removes perennial warm-season grasses and forbs (Baskin and Baskin 2000).

These glades are large enough (many in excess of 81 ha) that dolomite rock formations manifest themselves as linear stratified rock outcrops, ledges, and slab boulders interspersed with stony and gravelly dolomite and chert rubble. Flat ledgetops characteristically form ephemeral pools while calcareous seeps occasionally occur, particularly in association with outcrops of stratified Ordovician age dolomites. These variations within the dolomite glade community result in the development of a highly diverse, prairie-like shrub and herb groundcover. Dominant grasses include little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*) and prairie dropseed (*Sporobolus heterolepis*). These associates often form the co-dominant grass matrix on high quality dolomite glades from which a rich herbaceous association is present. Characteristic plants include chinquapin oak (*Quercus muehlenbergii*), chitin wood (*Bumelia lanuginosa*), big bluestem (*Andropogon gerardii*), low calamint (*Calamintha arkansana*), Missouri primrose (*Oenothera macrocarpa*), Missouri orange coneflower (*Rudbeckia missouriensis*) and orange puccoon (*Lithospermum canescens*). Numerous plant species occur only on dolomite glades, several of which are relicts or endemics to the Ozark Highlands including stenosiphon (*Stenosiphon linifolius*), Trelease's larkspur (*Delphinium treleasei*) (RFSS), and cusp gayfeather (*Liatris mucronata*).

The Ozark Ashe's Juniper Glade, restricted to the White River Subsection, was the equivalent of Xeric Limestone/Dolomite Forest (Nelson 1985) that was later merged into Dry Limestone/ Dolomite Cliff as a predominant component of cliff natural communities (Nelson 2010). However, some glades in the White River Hills Subsection have virgin Ashe's Juniper (*Juniperus ashei*) populations, likely because these glades occur in and around deeply-dissected hills of entrenched White River meanders protected in fire-shadows. A review of the associated herbaceous plant species and any possible species of conservation concern shows that herbaceous species are the same as those found on Ozark Dolomite Glades. Further, the glade mapping project for the White River Hills includes this association. While Ashe's Juniper is not tracked by the Missouri and Arkansas natural heritage programs as a species of conservation concern, analysis of the data will consider protection of this association in the conservation strategies section of this assessment.

The Arkansas portion of the White River Hills includes both extensive dolomite glades and large sandstone "flatrocks" of the St. Peter Sandstone Formation in Marion, Baxter, Stone, and Izard counties. These expansive, relatively flat glades support viable populations of eastern collared lizards, lichen grasshoppers, large-flowered tickseed (*Coreopsis grandiflora* var. *saxicola*), and other rare plants and animals. Sandstones of the St. Peter Formation are commonly cemented with calcite (McFarland 1998) and often support a flora more typical of limestone or dolomite glades. However, acidic glades do occur where outcrops are the local high point in the landscape and all calcareous material has been leached out or otherwise weathered away from the bedrock and associated soils. In addition, these sandstone glades may be overlain by dolomite, which forms calcareous glades and may influence the pH and flora of underlying sandstone glades. As a result, it is not uncommon to have both calcareous and acidic sandstone glades in close proximity where topography is varied.

The flora of the White River Hills glades and bluffs includes not only a number of regionally endemic taxa but also a number of taxa with western and/or southwestern affinities, some disjunct from the blackland prairies of the West Gulf Coastal Plain or the Edwards Plateau of Texas. Examples of such disjunct species include Texas Indian mallow (*Abutilon fruticosum*), powdery cloak fern (*Argyrochosma dealbata*), purple three-awn (*Aristida purpurea*), white sagebrush (*Artemisia ludoviciana* ssp. *mexicana*), rainlily (*Cooperia drummondii*), bighead rabbit tobacco (*Diaperia prolifera*), narrowleaf puccoon (*Lithospermum incisum*), few-flower stickleaf (*Mentzelia oligosperma*), knotweed leaf-flower (*Phyllanthus polygonoides*), and cedar sedge (*Carex planostachys*).

Several excellent examples of these glade/woodland landscapes occur on the Sylamore District of the Ozark National Forest, the Buffalo National River (especially in the Lower Buffalo Wilderness Area), and at Devil's Knob-Devil's Backbone Natural Area. Additional glades occur on Army Corps of Engineers land around Bull Shoals and Beaver Lakes and at Slippery Hollow Natural Area. Glades at all of these sites are being restored using prescribed fire and, in most cases, some form of mechanical removal of eastern red cedar.

Elk River Hills Subsection (223Ah)
Missouri: 134,114 ha
Arkansas: 23,401 ha
Oklahoma: 1108 ha

This subsection lies in extreme southwest Missouri and northern Arkansas consisting of the moderately dissected hills of the Elk River drainage. Geology is primarily a complex sandwich of cherty dolomites of the Burlington Formation, shales, and Devonian limestones. Small limestone glades often strewn with chert rubble occur here perhaps totaling 220 ha in Missouri.

Limestone glades in the Arkansas portion of the Elk River Hills Subsection are small and few in number but are known to support several plant species of conservation concern. Numerous small glades on limestone, sandstone, and dolomite occur in the dissected portions of the Springfield Plateau Subsection in Arkansas and support more than 20 plants of state conservation concern. Protected glades occur in this subsection at Hobbs State Park Conservation Area, the McIlroy-Madison County Wildlife Management Area, and the Buffalo National River.

Prairie Ozark Border Subsection (223Ai)
Missouri: 227,228 ha

This subsection is a high, smooth plain that was historically covered by tallgrass prairie and savanna. Western wallflower (*Erysimum capitatum*) is known from a few small glades in this subsection.

Inner Ozark Border Subsection (223Aj)
Missouri: 595,264 ha

This elongated, arc-shaped subsection occurs along the outer north and east flank of the Ozark uplift where rock formations dip steeply away from the Ozark dome center. This subsection includes a wide variety of rock types ranging from cherty dolomites of the Ordovician Jefferson City-Cotter Formation to the Ordovician LaMotte Formation, containing sandstones. This subsection includes a large complex of dolomite glades centered in Jefferson County immediately south of St. Louis. Mapped thus far are: 2,152 dolomite glades (largest 27 ha) totaling 1,585 ha and 110 sandstone glades (largest 1.4 ha) totaling 25 ha. The highest concentration of LaMotte sandstone glades occur in St. Genevieve County. St. Peters sandstone forms glades along escarpments near Hermann. Fewer glades occur along the western end of the subsection where deep loess covers much of the landscape. Ralph Erickson (1942) published on the significance of this glade region including the importance of glade habitat isolation in explaining genetically distinct morphological differences among populations of Fremont's leather flower (*Clematis fremontii* var. *riehlii*).

Outer Ozark Border Subsection (223Ak)

Missouri: 1,062,034 ha

Despite the size of this rather large arcing subsection along the outermost north and east flank of the Ozark Highland uplift, only the western portion is included in the CHJV geographical region. This subsection consists of a belt of deeply dissected hills and blufflands bordering the Missouri River. Because slopes are steep and geology complex, rock substrate exposures are common. The Mississippian Burlington Formation forms a prominent escarpment, forming a bold line of hills where dolomites and sandstones occur. A small but significant area of dolomite glades of the Jefferson City-Cotter Formation occur in the dissected hills north and east of Jefferson City while sandstone glades of the St. Peter's Formation occur throughout. The occurrence of glades rapidly diminishes west of the Missouri River at Jefferson City. An estimated 405 ha occur here.

Black River Ozark Border Subsection (223Al)
Missouri: 355,864 ha

No glades presently are recorded from this subsection. However, the comprehensive Missouri glade inventory will examine this subsection in 2013.

Springfield Plain Subsection (223Am)
Missouri: 127,618 ha
Oklahoma: 170,089 ha

This large, smooth plain of the southwestern Ozark Highlands has relief generally less than 46 m. However, Pennsylvanian and Mississippian age limestone, sandstone and chert barren rock outcrops produce exceptional and globally distinctive glade types. These include the Ozark Chert Glades (CEGL002244) of the Grand Falls Formation near Joplin. Ernest J. Palmer, a noted botanist from Arnold Arboretum of Harvard University studied the chert glades of Joplin, having lived in nearby Webb City until his death. He published the Flora of the Grand Falls Chert Barrens in 1910. Private conservation organizations in Joplin lobbied to protect these globally distinctive chert glades. The Missouri Department of Conservation, in partnership with the local Audubon Chapter, has constructed a nature center that interprets the significance of Chert Glades. Approximately 30 Chert Glades totaling 40.5 ha occur within 16 km of Joplin, making this glade type the most restricted and rarest of glades in the Ozark Highlands of Missouri, and the world. Characteristic plant species on the deeper, perennial-grass forming soil include little bluestem (*Schizachyrium scoparium*), tickseed coreopsis (*Coreopsis lanceolata*), hairy wild petunia (*Ruellia humilis*), scaly gayfeather (*Liatris squarrosa*) and wild hyacinth (*Camassia scilloides*). Shallow soil plants over chert bedrock include rushfoil (*Crotonopsis elliptica*), aromatic aster (*Symphyotrichum oblongifolium*), selenia (*Selenia aurea*), Bush's sedge (*Carex bushii*), tufted marshallia (*Marshallia caespitosa*), eastern prickly pear (*Opuntia humifusa*), widow's cross (*Sedum pulchellum*), sandwort (*Arenaria patula*), small-flowered fameflower (*Talinum parviflorum*), and rock spikemoss (*Selaginella rupestris*). Species restricted to chert glades in Missouri include Nuttall's sedum (*Sedum nuttallianum*) and singletary vetchling (*Lathyrus pusillus*), believed to be extirpated.

Ninety-seven km to the east of Joplin, near Springfield, is a local complex of Ozark Limestone Glades (CEGL002251). This is one of the most important ecological areas in Missouri for high concentrations of limestone glades with 60 mapped occurrences totaling 162 ha. Unlike the typical glades of steeper dissected Ozark hills, the limestone glades of the Springfield Plains are more exposed bedrock pavements occurring on gentle-sloping upland plains. A classic example is Rocky Barrens Conservation Area, about 16 km north of Springfield. These limestone glades harbor the highest concentrations of the federally listed Missouri bladderpod (*Physaria filliformis*). Another species of conservation concern confined to limestone glades is stiff greenthread (*Thelesperma filifolium*). The purple paintbrush (*Castilleja purpurea*) was known only from these limestone glades but is extirpated from Missouri.

Among the various Ozark Sandstone Glade types (CEGL002242), Pennsylvanian sandstone substrates form some of Missouri's largest sandstone glades. An example is Halltown Glade in Lawrence County, a sandstone glade that is nearly .80 km long. Some of these sandstone glades extend into prairies such as those found on Taberville Prairie Natural Area in St. Clair County. Characteristic plants in this region include rock spikemoss (*Selaginella rupestris*), common leastdaisy (*Chaetopappa asteroides*), pinweed (*Lechea tenuifolia*), thread-leaved sundrops (*Oenothera linifolia*), selenia (*Selenia aurea*), mealy corydalis (*Corydalis crystallina*), and a saxifrage (*Saxifraga texana*). Geocarpon (*Geocarpon minimum*), Nuttall's sedum (*Sedum nuttalianum*), and purslane (*Portulaca pilosa*) are restricted to sandstone glades in southwest Missouri and to saline soil barrens in small portions of western and southeastern Arkansas, Louisiana, and Texas

Springfield Plateau Subsection (223An)
Arkansas: 668,444 ha
Oklahoma: 466,543 ha
Missouri: 12,268 ha

A limited number of small limestone glades occur within the Missouri portion of this subsection.

Mississippi River Alluvial Plain Subsection (223Ao)
Illinois: 153,679 ha
Missouri: 32,936 ha

The floodplain of this river landscape does not produce glades.

Missouri River Alluvial Plain Subsection (223Ap)
Missouri: 126,786 ha

The floodplain of this river landscape does not produce glades.

Illinois Ozarks Subsection (223Aq)
Illinois: 186,794 ha

Sitting on top of the Bailey Limestone (with a thin mantle of Peoria Loess) is a 1.2-ha limestone barren occurring at Larue Pine Hills Research Natural Area (Shawnee National Forest). Chinquapin oak (*Quercus muehlenbergii*), post oak (*Q. stellata*), and red cedar (*Juniperus virginiana*) line the edges. Winged elm (*Ulmus alata*), farkleberry (*Vaccinium arboretum*), and aromatic sumac (*Rhus aromatic*) are present as shrubs. The opening is dominated by side oats grama (*Bouteloua curtipendula*), with some little bluestem (*Schizachyrium scoparium*), and sheathed dropseed (*Sporobolus vaginiflorus*). Spreading aster (*Symphyotrichum patens*) is abundant. Kurz (1981) showed differences and similarities in the limestone glade flora in southern Illinois. Over 90 plant species were found on glades in the Lesser Shawnee Hills, while 83 species occurred in the Illinois Ozarks.

Boston Mountains Section (M223A) (1,692,782 ha total in Arkansas and Oklahoma):

Boston Mountains Subsection (M223Aa)
Arkansas: 420,236 ha

The Boston Mountains subsection includes the highest elevations in the Ozark Highlands Ecological Section. It consists of a series of low mountains (300–825 m in elevation) underlain by Pennsylvanian sandstone and shale (Foti and Bukenhofer 1998, Woods et al. 2004). This landscape is sufficiently elevated from the surrounding region to have lower temperatures and higher precipitation, which have resulted in different plant communities, including a number of mesic hardwood forest communities (Foti and Bukenhofer 1998). Glades do occur in this subsection, though most are small and are associated with blufftops on sandstone and, in some places, limestone. The highest concentrations of limestone glades in this subsection occur along the upper Buffalo River and its tributaries where streams have deeply dissected the landscape and cut through several limestone-containing formations including the Pitkin Limestone and the Boone Formation.

Protected examples of glades in this subsection occur on the Ozark National Forest, the Buffalo National River, Sweden Creek Falls Natural Area, and Kings River Falls Natural Area.

Boston Hills Subsection (M223Ab)
Arkansas: 972,565 ha
Oklahoma: 299,981 ha

The Boston Hills subsection occurs in Oklahoma and Arkansas. This subsection consists of high hills (150–550 m in elevation) underlain primarily by Pennsylvanian sandstone and shale. The

geology underlying the western portion of this subsection is Atoka Sandstone, while that in the eastern portion is the Bloyd Shale and Prairie Grove Member of the Hale Formation (Haley et al. 1976; Foti and Bukenhofer 1998). A smaller area in the northern portion of the subsection is underlain by the Pitkin Limestone. Shortleaf pine is common, and much of this region is covered by pine-oak and oak woodlands and forests. Sandstone glades occur on blufftops, benches, and ridges. While typically small, sandstone glades in this subsection often include seasonally wet zones of groundwater seepage, which support several rare plant species, including small-head pipewort (*Eriocaulon koernickianum*), Wolf's spikerush (*Eleocharis wolfii*), Muehlenberg's nutrush (*Scleria muehlenbergii*), and zigzag bladderwort (*Utricularia subulata*). Several of these wet glades grade into seasonally wet forested flatwoods or depression wetlands.

Protected examples of glades in this subsection occur on the Ozark National Forest, Devil's Den State Park, and on Army Corps of Engineers land around Greers Ferry Lake. Restoration work is being conducted at several sites on the Ozark National Forest.

Protection and Management

An active management program is critical to restore and/or maintain glade natural communities and sustain their elements. At the forefront of such programs are efforts to manage representative landscapes, incorporating glades and woodlands into large management units that have restorable qualities. The management challenge is to implement actions that sustain those elements of biodiversity that are both characteristic and least represented, particularly species of conservation concern. Determining management actions must take into account the original presumed character of the vegetation and retain, reestablish, or emulate the complex suite of disturbance processes that guided the composition of area biota. This will vary for each of the 24 glade association types.

Glade management actions depend on the following:

- An ecological assessment to determine quality characteristics.
- The degree to which the glade and surrounding associated woodlands are degraded.
- How this degradation is manifested in terms of out-of-character vegetation composition and structure.
- The area's presumed historical disturbance regime.
- The presence of invasive exotic species.
- The acceptance of ecological restoration theory.
- Adaptive management based on frequent monitoring.

For those glades occurring in the Ozark Highlands, most have suffered the degrading effects of overgrazing, soil loss, and the subsequent increase in woody vegetation, especially red cedar. Removal of invasive red cedar, especially older, thicker stands, is an important first step. Prescribed burning generally is not effective in removing dense, older stands of red cedar. Once

red cedar is removed, prescribed burning becomes more effective in restoring glade vegetation and later mimicking natural fire regimes (McCarty 1998).

Glades are not suitable for domestic livestock grazing given their highly degraded condition and sensitivity. The glade environment is too droughty and soils too thin to support any immediate recovery of the once deeper, now eroded soils and their diverse cover of perennial grasses, sedges and wildflowers. Amelon (1991) assessed the "effects of cedar harvest, prescribed fire and cattle grazing on glade productivity, nutrient cycling and hydrology of formerly grazed glades on the Mark Twain National Forest." While this study concluded vegetation productivity increased from burning and harvesting treatments, later analysis during the revision of the Forest Plan (2005) for the Mark Twain National Forest concluded that the cumulative effect of grazing glades for decades had caused the eventual loss of thin soil and degradation of rich plant communities (Smith 1990; Ladd and Heumann 2006). Interest groups should remain vigilant over any future attempts by the Forest Service to consider reinstating grazing back to glades and associated woodlands.

Infestations of invasive plant species should be controlled using integrated techniques including the selective use of herbicides and/or prescribed fire. Reseeding with native grasses and forbs may be necessary to compete with severe infestations of exotic plants or opportunistic native woody species.

Fire Management

Fire is the most efficient method available to treat large areas and move them toward the desired future condition (Nelson 2010). Landscape burns may consume a portion of downed woody material, a substantial portion of leaf litter, and kill some percentage of understory woody vegetation to allow sunlight to reach the forest floor (Stritch 1990). Conditions may occasionally cause stand replacement. Several years may pass before enough fuel accumulates to carry fire across some barrens areas. Other sites may be ready for the next burn in a year or two.

Spring burns are patchier, leaving more refugia for small animals. Prescribed fire can bring on unexpected results. Although burned in the spring preceding the near record drought of 1988, populations of the federally threatened Mead's milkweed (*Asclepias meadii*) on the Shawnee National Forest flowered for the first time in 5 years (Stritch 1990). On the Hoosier National Forest, prairie parsley (*Polytaenia nuttallii*) appeared after a prescribed fire in 1991. It became the second known site for the species in southern Indiana.

To mediate the potential negative effects that burning smaller glades has on insect species that overwinter in the duff and leaf litter layers, small prescribed burn units should be designed to burn only portions of the area, while other unburned sites are left as sources to recolonize the burned area. The best means of reducing these effects is to design large landscapes in the thousands of ha that include glades so the effects of prescribed burns are mitigated by the sheer size of the landscape. As likely occurred historically, large landscape burns left islands of

unburned vegetation due to variations in fuels, topography, soil moisture, natural barriers to fire spread and changes in weather conditions.

The Ouachita Mountains extend from central Arkansas westward to Atoka County, Oklahoma. They are unique among the areas covered in this assessment for their east-west trending ridges and warped, twisted, and folded beds of rock (Robison and Allen 1995). They are a continuation of the Appalachians, formed during the late Paleozoic Era when continents collided, causing marine sediments to be folded, faulted, and thrust northward (Woods et al. 2004). The Ouachitas are structurally different and more folded and rugged than the lithologically distinct Ozark Highlands and physiographically unlike the Arkansas Valley (Woods et al. 2004). They compose a belt about 95 km wide and 195 km long and include elevations up to 818 m at the top of Rich Mountain northwest of Mena, Arkansas. Principal rock types are Paleozoic sedimentary sandstones, shales, and cherts (including novaculite) ranging from Ordovician to Pennsylvanian in age (Robison and Allen 1995, Haley et al. 1976).

Natural vegetation is predominantly oak-hickory-pine forest and woodland with pine, common to dominant on south-facing slopes, with hardwoods often dominant on north-facing slopes. Glades and open, xeric woodlands occur on sandstone and chert/novaculite ridgetops and upper south-facing slopes and, less commonly, on shales in valleys and on slopes, especially along streams. Calcareous rock is uncommon but does occur as thin layers of limestone interbedded in some shale formations including the Mazarn, Womble, and Polk Creek shales (McFarland 1998). The Arkansas Novaculite is divided into three divisions (Upper, Middle, and Lower), and McFarland (1998) also notes that the Upper Division of the Arkansas Novaculite is often calcareous. Both of these calcareous rock types occasionally form glades that include plants associated with calcareous to circumneutral sites (Theo Witsell, personal communication).

The Ouachita Mountains contain a number of endemic or near-endemic plant and animal species, including several plant species found in glades and associated woodlands. These species include Ouachita blazing star (*Liatris squarrosa* var. *compacta*), Ouachita leadplant (*Amorpha ouachitensis*) (RFSS), Waterfall's sedge (*Carex latebracteata*), Pine-oak jewelflower (*Streptanthus squamiformis*), Clasping jewelflower (*Streptanthus maculatus* ssp. *obtusifolius*), Ouachita bluet (*Houstonia ouachitana*), maple-leaf oak (*Quercus acerifolia*), Ouachita bluestar (*Amsonia hubrichtii*), Pelton's rose-gentian (*Sabatia arkansana*), Ouachita goldenrod (*Solidago ouachitensis*), Cossatot leafcup (*Polymnia cossatotensis*), Nuttall's cornsalad (*Valerianella nuttallii*) (RFSS), and Palmer's cornsalad (*Valerianella palmeri*) (RFSS) (Zollner et al. 2005, Pringle and Witsell 2005).

Ouachita Mountains Section (M231A)
2,886,857 ha total in Oklahoma and Arkansas

Fourche Mountains Subsection (M231Aa)
Arkansas: 465,124 ha
Oklahoma: 414,564 ha

This subsection consists of open low mountain ridges, often with wide valleys, 230–850 m in elevation. Long east-west trending ridges are formed by Pennsylvanian and Mississippian sandstones with shale and sandy residuum in valleys (Foti and Bukenhofer 1998, Woods et al. 2004). The matrix vegetation is shortleaf pine and oak woodlands and forests. Glades in the Fourche Mountains are primarily sandstone and occur on ridges or south-facing slopes where they grade into xeric woodlands. Steep glades may occur on all aspects where streams cut through these ridges. Some small shale glades occur in valleys or on steep slopes along streams.

Several globally rare plant species occur in glades and associated woodlands in the Fourche Mountains including Ouachita leadplant (*Amorpha ouachitensis*) (RFSS), openground whitlow-grass (*Draba aprica*) (RFSS), Church's wild rye (*Elymus churchii*), Texas fescue (*Festuca versuta*), maple-leaf oak (*Quercus acerifolia*), and Ouachita blazing star (*Liatris squarrosa* var. *compacta*).

Woods et al. (2004) include the southeastern part of the Eastern Arkansas Valley and Ridges subsection of the Arkansas Valley (231Ga) in the Fourche Mountains Level IV Ecoregion based on similarities of the geology, landforms, and vegetation to that part of the Fourche Mountains west of the Arkansas River.

West Central Ouachita Mountains Subsection (M231Ab)
Oklahoma: 587,026 ha
Arkansas: 329,658 ha

This subsection consists of open high hills and low mountains, often with wide valleys, 230–760 m in elevation, underlain by Mississippian sandstone and shale with clayey colluvium. The matrix vegetation is shortleaf pine-oak and oak woodlands and forests, along with prairies in the valleys (Foti and Bukenhofer, 1998). Glades are primarily sandstone and shale. Sandstone glades occur on ridges or south-facing slopes where they grade into xeric woodlands. Shale glades occur in valleys or along streams. Some small novaculite glades occur in the western portion of the subsection, though this may be an artifact of the coarse scale at which the subsections were mapped.

Shale glades in the West Central Ouachita Mountains also include a number of globally rare plant species, including Ouachita blazing star (*Liatris squarrosa* var. *compacta*), Ouachita leadplant (*Amorpha ouachitensis*) (RFSS), Waterfall's sedge (*Carex latebracteata*), Pine-oak jewelflower (*Streptanthus squamiformis*), Clasping jewelflower (*Streptanthus maculatus* ssp.

obtusifolius), Ouachita bluets (*Houstonia ouachitana*), small-headed pipewort (*Eriocaulon koernickianum*), open-ground whitlow-grass (*Draba aprica*) (RFSS), Shinner's sunflower (*Helianthus occidentalis* ssp. *plantagineus*) (RFSS), Nuttall's cornsalad (*Valerianella nuttallii*), and Palmer's cornsalad (*Valerianella palmeri*) (RFSS). They also support several other state species of conservation concern including wild crocus (*Tradescantia longipes*) and tufed marshallia (*Marshallia cespitosa* var. *cespitosa*). Sandstone and shale glades are protected in the Ouachita National Forest and at Cossatot River State Park-Natural Area. Additional shale glades are protected on land owned by the Army Corps of Engineers around Lake Ouachita.

East Central Ouachita Mountains Subsection (M231Ac)
Arkansas: 487,221 ha

This subsection consists of open high hills and low mountains, often with wide valleys, 230–760 m in elevation, underlain by Mississippian sandstone, shale, chert, and novaculite with clayey colluvium (Foti and Bukenhofer 1998). The landscape in this section is characteristically steep and rugged and rock outcrops, and shallow, stony soils are widespread (Woods et al. 2004). The matrix vegetation is shortleaf pine-oak and oak woodlands and forests. Glades occur on several rock types including novaculite, chert, sandstone, and shale. Novaculite, chert, and sandstone glades occur primarily on ridges and upper south-facing slopes but may occur on all aspects where streams cut through these ridges. Shale glades occur in valleys or along headwater streams where the geology is appropriate.

Novaculite glades in the East Central Ouachita Mountains support a number of globally rare plant species including Ouachita blazing star (*Liatris squarrosa* var. *compacta*), Waterfall's sedge (*Carex latebracteata*), Pine-oak jewelflower (*Streptanthus squamiformis*), clasping jewelflower (*Streptanthus maculatus* ssp. *obtusifolius*), Ouachita bluets (*Houstonia ouachitana*), maple-leaf oak (*Quercus acerifolia*), Ouachita goldenrod (*Solidago ouachitensis*), Cossatot leafcup (*Polymnia cossatotensis*), Church's wild rye (*Elymus churchii*), and Texas fescue (*Festuca versuta*). Other state species of conservation concern found in novaculite glades in this subsection include wavy hairgrass (*Deschampsia flexuosa*) and Riddell's spikemoss (*Selaginella arenicola* ssp. *riddellii*).

Shale glades in the East Central Ouachita Mountains are exceptionally diverse and support many globally rare plants including Missouri bladderpod (*Physaria filiformis*), Ouachita blazing star (*Liatris squarrosa* var. *compacta*), Ouachita leadplant (*Amorpha ouachitensis*) (RFSS), Ouachita bluestar (*Amsonia hubrichtii*), openground whitlow-grass (*Draba aprica*), plantain-leaf sunflower (*Helianthus occidentalis* ssp. *plantagineus*) (RFSS), Waterfall's sedge (*Carex latebracteata*), clasping jewelflower (*Streptanthus maculatus* ssp. *obtusifolius*), Pelton's rose-gentian (*Sabatia arkansana*), royal catchfly (*Silene regia*) (RFSS), Nuttall's cornsalad (*Valerianella nuttallii*), and Palmer's cornsalad (*Valerianella palmeri*) (RFSS). Other species of state conservation concern found in shale glades in this subsection include dwarf spiderwort (*Tradescantia longipes*), rough rattlesnake-root (*Prenanthes aspera*), wedge-leaved spurge (*Euphorbia longicruris*), heartleaf skullcap (*Scutellaria cardiophylla*), western silky aster

(*Symphyotrichum sericeum*), Nuttall's pleatleaf (*Nemastylis nuttallii*), and tufed marshallia (*Marshallia caespitosa* var. *caespitosa*).

All glade types are protected in the Ouachita National Forest. Additional shale glades are protected at Middle Fork Barrens Natural Area and on land owned by the Army Corps of Engineers around Lake Ouachita. Additional novaculite glades are protected at Lake Catherine State Park and The Nature Conservancy's Trap Mountain Preserve.

Athens Piedmont Plateau Subsection (M231Ad)
Arkansas: 366,209 ha
Missouri: 245,146 ha

This subsection consists of open high hills, 150–300 m in elevation, underlain by Mississippian and Pennsylvanian sandstone and shale with sandy and clay-loam colluvium (Foti and Bukenhofer 1998, Woods et al. 2004). The matrix vegetation is shortleaf pine-oak and oak woodlands and forests. This subsection includes glades on shale and sandstone substrates.

Shale glades in the eastern portion of the Athens Piedmont Plateau include a number of globally rare plant species including Missouri bladderpod (*Physaris filiformis*), three-flowered hawthorn (*Crataegus triflora*), Ouachita blazing star (*Liatris squarrosa* var. *compacta*), Ouachita leadplant (*Amorpha ouachitensis*) (RFSS), openground whitlow-grass (*Draba aprica*) (RFSS), Waterfall's sedge (*Carex latebracteata*), Clasping jewelflower (*Streptanthus maculatus* ssp. *obtusifolius*), royal catchfly (*Silene regia*) (RFSS), Nuttall's cornsalad (*Valerianella nuttallii*) (RFSS), and Palmer's cornsalad (*Valerianella palmeri*) (RFSS). Other species of state conservation concern found in shale glades in this subsection include wedge-leaved spurge (*Euphorbia longicruris*), and heartleaf skullcap (*Scutellaria cardiophylla*).

Protected examples of shale glades in the Athens Piedmont Plateau can be found at the Cossatot River State Park-Natural Area and on lands owned and managed by The Ross Foundation, a non-profit organization with significant land holdings in the subsection.

Arkansas Valley Section (231Ga)
2,506,935 ha total in Arkansas and Oklahoma

The Arkansas Valley is a synclinal and alluvial valley lying between the Boston Mountain/Ozark Highlands and the Ouachita Mountains (Woods et al. 2004). This section is diverse and transitional, containing plains, hills, floodplains, terraces, and scattered mountains. It is largely underlain by interbedded Pennsylvanian sandstone, shale, and siltstone (Haley et al. 1976, Woods et al. 2004). Natural vegetation in uplands is a mix of forest, woodland, savanna, and prairie, and natural vegetation of floodplains and lower terraces is bottomland deciduous forest (Woods et al. 2004).

Glades in this section are not extensive but are ecologically important and support a number of species of conservation concern.

Eastern Arkansas Valley and Ridges Subsection (231Ga)
Arkansas: 1,218,110 ha

The Eastern Arkansas Valley and Ridges subsection occurs only in Arkansas, where it is characterized by plains with hills from 90-150 m in elevation, underlain by Pennsylvanian sandstone and shale with sandy residuum. The matrix vegetation is shortleaf pine-oak and shortleaf pine woodland and forest. Sandstone glades occur on ridges, benches, gentle south-facing slopes, and above bluffs.

Of particular interest in this subsection are glades on Horseshoe Mountain and Short Mountain, two flat-topped mesas in Franklin and Logan counties underlain by the Boggy Formation. These glades support a number of rare plant species including white sagebrush (*Artemisia ludoviciana* ssp. *mexicana*), wedge-leaved spurge (*Euphorbia longicruris*), Texas bedstraw (*Galium texense*), rainlily (*Cooperia drummondii*), shortleaf rush (*Juncus brachyphyllus*), woolly plantain (*Plantago patagonica*), and rosemary rock-rose (*Helianthemum rosmarinifolium*).

Blufftop glades, such as those on Petit Jean Mountain, support several plant species of conservation concern including Church's wild rye (*Elymus churchii*), Ouachita blazing-star (*Liatris squarrosa* var. *compacta*), and Riddell's spikemoss (*Selaginella arenicola* ssp. *riddellii*). Also on Petit Jean Mountain are some of the largest sandstone glades in the Arkansas Valley, with the "Seven Hollows Glades" in Petit Jean State Park covering roughly 405 ha. These glades, in addition to supporting rare plant species, are home to a viable population of the eastern collared lizard.

Blufftop and steep slope andstone and shale glades along Cove Creek and Cadron Creek in this subsection support populations of several state species of conservation concern including openground whitlow-grass (*Draba aprica*), tall cinquefoil (*Potentilla arguta*) and yellow nailwort (*Paronychia virginica*).

Protected sandstone glades occur in this section on Petit Jean State Park and Cove Creek Natural Area.

Mount Magazine Subsection (231Gb)
Arkansas: 261,642 ha

This subsection includes Mt. Magazine, the highest point in the Interior Highlands at 839 m above sea level. Mt. Magazine supports sandstone glades and bluffs with a number of rare and/or disjunct plant species including western wallflower (*Erysimum capitatum*), small-headed pipewort (*Eriocaulon koernickianum*), Virginia nailwort (*Paronychia virginica*), and wavy hairgrass (*Deschampsia flexuosa*). Mt. Magazine is the type locality for the endemic Ouachita

leadplant (*Amorpha ouachitensis*) (RFSS) and supports large populations of Church's wild rye (*Elymuc churchii*) and mapleleaf oak (*Quercus acerifolia*). The top of Mt. Magazine is underlain by the McAlester Formation (Haley et al. 1976). It is the only site known in the Arkansas Valley of Arkansas with a population of Ashe's juniper (*Juniperus ashei*).

Much of the area in this subsection is contained within the Ozark National Forest. The top of Mt. Magazine is protected by Mt. Magazine State Park. The U.S. Forest Service and Arkansas State Parks are restoring glades and woodlands on the top of Mt. Magazine using prescribed fire.

Western Arkansas Valley and Ridges Subsection (231Gc)
Oklahoma: 961,256 ha
Arkansas: 65,991 ha

This subsection consists of plains, low hills, and ridges 90-300 m in elevation underlain by Pennsylvanian sandstone and shale with sandy and clayey residuum and Holocene sandy alluvium (Foti and Bukenhofer 1998). The matrix vegetation is shortleaf pine-oak and oak woodland and forest in upland areas and bottomland forest and prairie in valleys. It is not a major subsection for glades but does include some gladey shale outcrops in tallgrass prairie remnants. These sites support several plant species of conservation concern including rainlily (*Cooperia drummondii*), narrowleaf puccoon (*Lithospermum incisum*), and wild hyacinth (*Camassia angusta*). Examples of these shale outcrops occur on Fort Chaffee Military Reservation.

Arkansas Alluvial Plains Section (234E)

South Central Arkansas Subsection (231Ea)

Although not typical for the Arkansas Alluvial Plains of the Gulf Coastal Plain and the South Central Arkansas Subsection, this subsection contains a globally rare type of igneous glade in small areas of Pulaski and Saline counties in Central Arkansas, within a few km of the southern edge of the Ouachita Mountains (The Nature Conservancy 1996, The Nature Conservancy 2000, Witsell 2007). These glades occur on a granitic igneous rock called nepheline syenite. This igneous (nepheline syenite) batholith of Tertiary age is surrounded by unconsolidated sands and gravels (Gordon et al. 1958, Pringle and Witsell 2005). Glades occur at several sites on this igneous bedrock and support a number of rare plant species, some globally rare. The narrow endemic Pelton's rose-gentian (*Sabatia arkansana*) occurs in several of these nepheline syenite glades and at a single shale glade in the nearby Ouachita Mountains. It is endemic to Saline County, Arkansas and was described as a new species in 2005 (Pringle and Witsell 2005). It has a global conservation status rank of G1 (critically imperiled). The matrix vegetation is pine (loblolly and shortleaf), oak, oak forest, and woodland. The plant communities of these glades are described in detail by Witsell (2007).

Several of these glades include a seasonally wet component with a unique flora including several species of state, regional, and/or global conservation concern; small-headed pipewort (*Eriocaulon koernickianum*), low nutrush (*Scleria verticillata*), Muehlenberg's nutsedge (*Scleria muehlenbergii*), sheathed flatsedge (*Cyperus haspan*), zigzag bladderwort (*Utricularia subulata*), Pelton's rose-gentian (*Sabatia arkansana*), small-flowered fameflower (*Talinum parviflorum*), and Butler's quillwort (*Isoetes butleri*). Species of conservation concern from the drier glades include Texas fescue (*Festuca versuta*), prairie broomspurge (*Euphorbia missurica*), openground whitlow-grass (*Draba aprica*) (RFSS), buffalo clover (*Trifolium reflexum*), and Carolina clover (*Trifolium carolinianum*). These glades also support a population of glade onion (*Allium stellatum*), which is disjunct from the Ozark Highlands.

Nepheline syenite glades have declined in number, size, and quality from strip mining, development, invasive species infestation, and fire suppression (Pringle and Witsell 2005). Protected sites occur in Gillam Park in south Little Rock, Pulaski County, and at two preserves (Dry Lost Creek Preserve and Dunnahoo Preserve) owned by The Nature Conservancy in Saline County. All unprotected sites are threatened by mining and/or development. This habitat type is identified as a conservation priority in the Arkansas Wildlife Action Plan (Anderson 2006). The Nature Conservancy has restored glades on both of these preserves in Saline County, using a combination of cedar removal, prescribed fire, invasive Chinese privot (*Ligustrum sinense*) control, and mechanical thinning of the matrix woodlands. Restoration of glades in Gillam Park is in the planning stages.

Interior Low Plateau-Highland Rim Section (223E)

6,243,593 ha total in Kentucky, Tennessee and Alabama

The Interior Plateau of the Highland Rim Section (223Ee) occurs mainly within Tennessee but also includes portions of Kentucky and Northern Alabama (Fenneman 1917, McNab and Avers 1996). Some physiographic province or ecoregional maps (e.g., Fenneman 1938 in Braun 1950, Griffith et al. 1997) have slightly different section or subsection names and boundaries for regions within the Interior Plateau (sometimes referred to as the Interior Low Plateau). Although these boundaries differ, particularly in the northern sections, the differences within Tennessee appear to be nomenclatural and pertaining to scale of mapping, as opposed to a markedly different form of classification.

McNab et al. (1997) describe this area as a

> . . . level-bedded, uplifted plateau; surface is moderately to deeply dissected surface. Landforms are mostly open hills and irregular plains composed mainly of sandstones that weather to deep soils with subsoil high in clay content. The Nashville Basin forms a large inclusion with deeply dissected and undulating terrain. The oak-hickory cover type predominates.

According to Braun (1950) this area contains Western Mesophytic Forest, a transition between the Mixed Mesophytic Forest to the east and the Oak-Hickory Forest further west.

Primary Glade Systems

The Interior Low Plateau Highland Rim Section possesses two glade ecological systems as defined by NatureServe (2006); the Nashville Basin Limestone Glade and Barrens (CES202.334), and Central Interior Highlands Calcareous Glade and Barrens (CES202.691).

NatureServe (2006) lists Central Interior Highlands Dry Acidic Glade and Barrens (CES202.692) as potentially occurring within this region of Tennessee. However, the Tennessee Natural Heritage Program (TNHP 2011) is unaware of this system within the Interior Low Plateau Highland Rim Section. Acidic glades[2] similar to those of the Interior Low Plateau Shawnee Hills Section occur on exposed sandstone atop cliffs and other thin-soiled sites on the Cumberland Plateau but lie outside the Interior Low Plateau Highland Rim Section. Additional acidic glade communities are possible within the Coastal Plains Middle Section of Tennessee, but to-date TNHP knows of no such sites.

The Nashville Basin Limestone Glade and Barrens is limited to sites within the Inner and Outer Nashville Basin (223Ed). The Central Interior Highlands Calcareous Glade and Barrens occurs in small isolated patches along the escarpment of the Eastern Karst Plain and the Cumberland Plateau, with the higher quality occurrences on the western edge of the Western Pennyroyal Karst Plain (223Eg) (TNHP 2011).

In 2009 the Kentucky State Nature Preserves Commission (KSNPC) updated their *Kentucky Natural Communities* classification and delineated 6 types of Kentucky glades based on parent material and topographical position. Five limestone slope glades are known in this subsection on moderate slopes of Mississippian age limestones. They occur above tributaries of the Cumberland River (KGS 2004, KSNPC 2012). These glades are classified within the Central Interior Highlands Calcareous Glade and Barrens (CES202.691) system as well (NatureServe 2011).

KSNPC (2009) described 6 glade natural communities with only 2 of these found in the Bluegrass Section. These are shown below with the equivalent NatureServe Association:

KSNPC (2009)		**NatureServe**
Limestone flatrock glade	=	Limestone Annual Grass Glade
	&	Central Basin Limestone Glade Margin Shrubland

[2] Cumberland Sandstone Glade and Barrens (CES202.337).

	&	Interior Low Plateau Limestone Glade Ephemeral Pool
Limestone slope glade	=	Eastern Knobs Ledge/Cliff Glade Woodland (in part)
	&	Kentucky Glade Seep
	&	Central Limestone Glade

Total area mapped: Kentucky: this subsection contains 5 mapped limestone slope glades totaling 4.5 ha (KSNPC 2012).

Glade area under protection: (KY ONLY DATA)

Federal: None State: None TNC: None Other NGOs: None

Plant and animal species of conservation concern:

The following is a list of rare Kentucky glade plants in this subsection (extant) (KSNPC 2012):

Glade Obligate or Optimal: Crawe's sedge *(Carex crawei),* thread-leaf sundrops (*Oenothera linifolia*)

Glade Suitable or Marginal: Plains muhlenbergia (*Muhlenbergia cuspidata*)*,* rough dropseed (*Sporobolus clandestinus*)*.*

Eastern Highland Rim Subsection (223Ea)
Kentucky: 519,231 ha
Tennessee: 104,225 ha

Information not provided.

Eastern Karst Plain Subsection (223Eb)
Tennessee: 677,978 ha
Kentucky: 270,489 ha

The McNab et al. (1997) delineation of the Eastern Karst Plain appears analogous to the Eastern Highland Rim, as defined by Griffith et al. (1997).It is an ecoregion that contains a number of barrens sites significant for their plant species disjunct from the Coastal Plain (DeSelm 1990, McKinney 1989, McCoy and Bailey 2004). However, these barrens are deep-soiled and not classified as glades or rocky barrens. Limestone glade communities do occur within the boundaries of what McNab et al. (1997) classify as Eastern Karst Plain subsection, but the communities' presence in this subsection appears to be an artifact of scale rather that an accurate

delineation because they are located along the western escarpment to the Cumberland Plateau as defined by Griffith et al. (1997).

This area, consisting of limestone derived soils and limestone outcrops (Crabtree et al. 2007, Griffith et al. 1997, Estes and Fleming 2006, Chandler 1940), contains examples of Central Interior Highlands Calcareous Glade and Barrens on the most xeric sites (NatureServe 2006, TNHP 2011). Although small, these open, shallow-soiled areas contain a glade/barren flora including grasses such as little blue stem (*Schizachyrium scoparium*), Indian grass (*Sorghastrum nutans*), sheathed dropseed (*Sporobolus vaginiflorus*), and side-oats gamma (*Bouteloua curtipendula*). Some of the forbs within these glades are more prevalent among the western plains or midwestern prairies. These include white prairie-clover (*Dalea candida*), Canada milk vetch (*Astragalus canadensis*), prairie goldenrod (*Oligoneuron album*), Great Plains ladie's-tresses (*Spiranthes magnicamporum*), McDowell's sunflower (*Helianthus occidentalis*), and slender blazing-star (*Liatris cylindracea*).

Outer Nashville Basin Subsection (223Ec)
Tennessee: 1,049,606 ha
Kentucky: 58,692 ha

As with the Inner Nashville Basin, the Outer Nashville Basin contains Nashville Basin Limestone Glade and Barrens (CES202.334) system and its community associations. Glades within these two subsections possess a similar flora and Ordovician age limestone. However, except for some large glade complexes along the Duck River in Maury County, Tennessee, glades within the Outer Nashville Basin subsection are few and are often isolated, small openings within dry oak or cedar woodlands that lack the strict endemics (TNHP 2011). Rather than glades, much of the Outer Nashville Basin possesses forested communities, some of which are high-quality mesic forests with showy displays of spring wildflowers (Alcorn 1973, TNHP 2011).

In Kentucky, glade development is poor with no high-quality occurrences known. A few eroded shale/siltstone glades have been identified in this subsection (KSNPC 2011).

Threats to glades of the Outer Nashville Basin include those common to glades in other subsections: exotic species (especially sericea lespedeza), off-road vehicle use, historic dumping, and grazing. Although glades of the Outer Central Basin haven't faced the development pressure that occurs within the Inner Central Basin, some small glade openings have been destroyed from housing developments, including one with the federally listed leafy prairie clover (*Dalea foliosa*).

Straddling the Inner and Outer Nashville Basin, the 5 180-haYanahli Wildlife Management Area contains some high-quality glade communities. This wildlife management area includes the 864-ha Duck River Complex State Natural Area. Composed of 6 separate units, this state natural area protects a number of state-listed glade plant species including the federally listed leafy prairie clover, a species which the Tennessee Division of Natural Areas regularly monitors. Ironically, the reason this area is publically owned results from an aborted Tennessee Valley Authority dam project. Had the dam been constructed as proposed, much of this area would have been inundated.

Other glades that occur on protected lands of the Outer Nashville Basin include a few sites on Army Corps property around J. Percy Priest Lake.

The presence of high-quality glade communities within the Outer Nashville Basin may be a result of subsection mapping scale. All of the large glade sites that support glade endemic species within the Outer Nashville Basin are adjacent to the Inner Nashville Basin (TNHP 2011).

Inner Nashville Basin Subsection (223Ed)
Tennessee: 411,381 ha

Glades within the Inner Nashville Basin are classified as Nashville Basin Limestone Glade and Woodland (CES202.334) (NatureServe 2006). Such glades have long been recognized for their significance due to their drought adapted flora and high number of endemic and plant taxa (Baskin and Baskin 1986). As early as the late 19th and early 20th centuries, geologists noted the substrate and vegetation type of cedar glades within the Inner Central Basin (Safford 1851, 1869, Killebrew and Safford 1874, Galloway 1919 *in* Quarterman 1950).

In his 1901 *Flora of Tennessee*, Augustin Gattinger wrote a brief floristic description of the cedar glades of the Inner Nashville Basin. Twenty years later, Roland Harper, a naturalist who worked in Georgia and Florida, traveled to the area to visit the cedar glades about which Gattinger wrote. After arriving in Nashville, Harper traveled by rail to Mt. Juliet in Wilson Co. and walked to Hermitage in Davidson Co., visiting and documenting the vegetation of several glades along his route (Harper 1926). Additional studies of glades followed: Picklesimer (1927) (synthesized in Baskin and Baskin 1996), Freeman (1933), Quarterman (1950), Somers et al. (1986), Drew (1991), Quarterman et al. (1993), Drew and Clebsch (1995), Rollins (1997), and Baskin and Baskin (2003). As a result of such studies, a number of sites have been recognized as significant at both the regional and national level and protected within the Tennessee State Natural Areas Program (Keever 1971, Bowen 2011).

The glades of the Inner Nashville Basin form a matrix of annual-grass dominated glades[3], deeper-soiled barrens, stunted cedar forests, cedar-hardwood forests, and deciduous forests

[3] NatureServe (2006) classifies this as Limestone Annual Grass Glade (CEGL004340).

(McKinney and Hemmerly 1984). For clarification, the regional term "cedar glade" refers to those habitats with exposed or nearly exposed limestone at the surface, low densities of trees and shrubs, having less than 50% cover of perennial grasses and little topographic relief. Under this definition, glades are considered an edaphic climax because succession to forest in the absence of burning or other management is unlikely (Baskin and Baskin 1999, 2000). This definition is consistent with that used by Quarterman (1989) and Baskin and Baskin (1986, 2003).

Although hot and dry during the summer, some of the open, rocky glades are seasonally wet and include a number of plant species adapted for wet areas for part of their growing season. Species such as yellow sunnybells (*Schoenolirion croceum*), Crawe's sedge (*Carex crawei*), and eastern yellow star-grass (*Hypoxis hirsuta*) occur in shallow standing or sometimes flowing water in the spring. Other seasonally wet areas include small, shallow depressions (sometimes just a few cm deep and a few m wide) with virtually no soil. Even some of the deeper soiled wet areas possess flowing water in the winter and spring and provide good habitat for the near-endemic and federally listed leafy prairie clover (*Dalea foliosa*) (TNHP 2011, Thompson et al. 2006). Currently, NatureServe (2006) lists 3 community associations for such wet areas within glades.[4]

Part of this mosaic includes shallow-soiled barrens.[5] Like the glades, barrens are also predominantly treeless, but differ from glades in that they possess greater than 50% grass cover, have greater soil depths, and have little exposed limestone (Quarterman 1989). Barrens also differ from glades in that the dominant grass of barrens is the perennial little bluestem (*Schizachyrium scoparium*), while the more common grass on glades is the annual sheathed dropseed (*Sporobolus vaginiflorus*). Without disturbance such as burning, mowing, or some other means of removal of woody species, barrens communities as well as glades with pockets of deeper soil are susceptible to woody plant succession, particularly from red cedar (Bailey et al. 2003, Baskin and Baskin 2004, Quarterman 1989). Although floristically interesting, the barrens of the Central Basin often lack the endemic and federally listed plant species.

Glades within the Interior Plateau often harbor disjunct and edemic plant taxa, but no section covered in this assessment contains as many endemics as the Inner Central Basin (Baskin and Baskin 1989). The cedar glades within this section contain four Tennessee endemic taxa: Pyne's groundplumb (*Astragalus bibullatus*), Tennessee coneflower (*Echinacea tennesseensis*), cedar glade cress (*Leavenworthia stylosa*), and interior phacelia (*Phacelia dubia* var. *interior*). In addition, this system contains the following southeastern endemics (Baskin and Baskin 1989): Gattinger's prairie clover (*Dalea gattingeri*), Carolina larkspur (*Delphinium carolinianum* ssp. *calciphilum*), Tennessee glade cress (*Leavenworthia exigua* var. *exigua*), pasture glade cress (*L. exigua* var. *lutea*), Gattinger's lobelia (*Lobelia appendiculata* var. *gattingeri*), Price's yellow

[4] Limestone Glade Streamside Meadow (CEGL004292), Limestone Seep Glade (CEGL004169), and Interior Low Plateau Limestone Glade Ephemeral Pool (CEGL004346).

[5] Presently this community is included in NatureServe's (2006) Central Limestone Glade (CEGL005131).

wood sorrel (*Oxalis priceae* ssp. *priceae*), southern scurfpea (*Pediomelum subacaule*), limestone fameflower (*Talinum calcaricum*), and running glade clover (*Trifolium calcaricum*).

Glades within the Inner Nashville Basin experience threats such as off-road vehicle use (even illegal use within protected state lands), exotic species, woody plant succession, and continued grazing. Impoundment of the Stones River by J. Percy Priest Dam in the late 1960s inundated a number of sites including glades with the now federally listed and strict endemic Pyne's ground plum and Tennessee coneflower.

However, by far the greatest threat to the long-term sustainability of glades within the Inner Nashville Basin is development. The edge of this flat subsection lies just southeast of Nashville and includes Rutherford County which, according to the last census, is the fasting growing county in Tennessee. A number of high-quality glades have been converted to subdivisions, highways, trucking logistical centers, and a motor speedway. Even when the development does not occur directly atop a glade, some protected glades have been degraded from increased water flow due to the reduction of nearby pervious surface. Other glades have been degraded from newly created exotic species corridors such as utility rights of way.

Although numerous glade sites have been destroyed or degraded, a number of high-quality glades are protected within the Inner Nashville Basin. The conservation activities of various government agencies and The Nature Conservancy have protected a number of glades and numerous rare plant species. The efforts of these groups, especially that of the Tennessee Division of Natural Areas, resulted in the federal de-listing of the endemic Tennessee coneflower (*Echinacea tennesseensis*), the first plant species listed under the federal endangered species act. (Bowen 2011).

Because of the number of federally listed and endemic plant species, the Inner Nashville Basin of Tennessee has received much attention in terms of research and monitoring. The Tennessee Natural Heritage Program's monitoring and protection of *Echinacea tennesseensis* populations aided in the species federal de-listing (Bowen 2011), and monitoring will continue at least through 2016 to ensure the species' recovery goals are maintained. In conjunction with the Tennessee Division of Forestry, the Tennessee Natural Areas Program continues using management tools such as mowing, cutting, and prescribed fire to ensure the sustainability of the glade communities and rare species protected within Tennessee's state natural areas.

Recently, the Center for Plant Conservation has successfully cultivated and introduced the federally endangered Pynes' ground plum (*Astragalus bibullatus*) to sites within its historic range. Center for Plant Conservation and the Tennessee Natural Heritage Program continue to monitor the viability of the native populations within state natural areas in Rutherford County.

Table 8. Public lands within the Inner Nashville Basin that contain glades.

MANAGED AREA	COMMENT	Hectares (ha)
Cedars of Lebanon State Natural Area (SNA)	Included within Cedars of Lebanon State Forest	417
Cedars of Lebanon State Forest		3,173
Cedars of Lebanon State Park		507
Couchville Cedar Glade SNA		52
Duck River Complex SNA*	Included within Yanhli WMA	1,057
Elsie Quarterman Cedar Glade SNA		77
Factory Road Glade SNA		19
Fate Sanders Barrens SNA		223
Flat Rock Cedar Barren and Glade SNA		848
Gattinger's Glade and Barrens SNA		57
Henry Horton State Park	Only a small portion of the park contains glades	1,520
John and Hester Cedar Glades SNA		46
Long Hunter State Park	Only a small portion of the park contains glades	2,682
Manus Road Cedar Glade SNA		18
Mount View Glade SNA		9
Overbridge SNA		72
Stones River Glade SNA		190
Sunnybell Cedar Glade SNA		51
Vesta Cedar Glade SNA		145
Vine Cedar Glade SNA		20
Wilson School Road SNA		58
Yanahli Wildlife Management Area	The best glades are included in Duck River Complex	13,708

*Occurs in both the Inner and Outer Nashville Basin

Highland Rim-Hilly and Rolling Subsection (223Ee)
Alabama: 1,618,072 ha
Tennessee: 42,936 ha

Based on data from TNHP (2011), this section does not contain any glade communities or sensitive species associated with glades. The dominant soil layer (at least within Tennessee) consists of deeper soils originating from loess or limestone residuum, and, except in areas of seasonal wetness and ponding, it is well-suited for agriculture (USDA 2004).

Tennessee-Gasper Valley Subsection (223Ef)
Alabama: 328,022 ha

In Kentucky, only 1 limestone slope glade is known in this subsection, occurring in the northernmost part over Menard limestone and classified as Central Interior Highlands Calcareous Glade and Barrens (CES202.691) (KSNPC 2012, NatureServe 2011). This site is a 27-ha Nature Conservancy preserve known as Aimee M. Rosenfield Memorial Preserve.

Total area mapped: Kentucky: This subsection contains 1 mapped limestone slope glade totaling .81 ha (KSNPC 2012).

Glade area under protection: (KY ONLY DATA)

Federal: None State: None TNC: .81 ha Other NGOs: None

Plant and animal species of conservation concern: In Kentucky, the Nature Conservancy's Aimee M. Rosenfield Memorial Preserve protects several rare glade-associated species including: cream wild indigo (*Baptisia bracteata var leucophaea*)(S3), hairy fimbristylis (*Fimbristylis puberula*)(S2), and prairie dropseed (*Sporobolus heterolepis*) (S1S2).

The following is a list of rare Kentucky glade plants in this subsection (extant or historic) (KSNPC 2012):

Glade Obligate or Optimal: Hairy fimbristylis (*Fimbristylis puberula*)

Glade Suitable or Marginal: Broadleaf beardgrass (*Gymnopogon ambiguus*), hair grass (*Muhlenbergia glabrifloris*), bearded rattlesnake-root (*Prenanthes barbata*), prairie dropseed (*Sporobolus heterolepis*), buffalo clover (*Trifolium reflexum*).

Western Pennyroyal Karst Plain Subsection (223Eg)
Tennessee: 1,176,294 ha
Kentucky: 169,225 ha
Alabama: 52,538 ha

Similar to the Pennyroyal Karst Plain, the Western Pennyroyal Karst Plain contains barrens sites including Western Highland Rim Prairie and Barrens (CES202.352). In addition to these deeper-soiled grasslands, the far western edge of this subsection contains open, rocky glades and barrens classified as Central Interior Highlands Calcareous Glade and Barrens (CES202.691) or more specifically, Moulton and Tennessee Valley Limestone Hill Barrens (CEGL004738), a globally rare plant community (NatureServe 2006).

Moulton and Tennessee Valley Limestone Hill Barrens occur on slopes of Silurian geologic age and often are dominated by big blue stem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), and little bluestem (*Schizachyrium scoparium*) with a scattering of twisted, open-grown red cedar trees. Within these grass-dominated communities there exist forbs that are disjunct or peripheral, often from points much further west. Such species include barrens silky aster (*Symphyotrichum pratense*), wedgeleaf draba (*Draba cuneifolia*), slender blazing-star (*Liatris cylindracea*), soft-hair false gromwell (*Onosmodium molle spp. bejariense* [*Onosmodium molle* ssp. *occidentale*], pitcher sage (*Salvia azurea* var. *grandiflora*), barbed rattlesnake root

(*Prenanthes barbata*), hairy fimbristylis (*Fimbristylis puberula*) (Guthrie 1989, TNHP 2011, Kartesz 2011), and Great Plains ladies'-tresses (*Spiranthes magnicamporum*) (Jones 2006).

Although the Western Pennyroyal Karst Plain lacks the endemic species found within the Nashville Basin glades, glades of these 2 sections share some botanical affinities, including slender heliotrope (*Heliotropum tenellum*), roundfruit St. John's wort (*Hypericum sphaerocarpum*), and small skullcap (*Scutellaria parvula*) (Guthrie 1989).

Unlike the intensity of ecological and botanical investigations afforded glades within the Inner Central Basin, these Silurian-aged glades and barrens have received little floristic study in the past, and Guthrie's 1989 report remains the best and perhaps only such survey of glades in this area. Historically, these communities have been noted for their interesting geology and as early as the 1840s one geologist referred to a formation in this region as a "mound glade" and noted such is:

> Any conical hill capped by the whitish clays and soft limestones . . . These whitish calcareous clays . . . form soils which are unfavorable for the growth of most plants. A scanty growth of grass, a considerable number of cedars and a few stunted oaks, too low to be called trees, usually occupy a comparatively small part of the exposures, leaving most of the hillside open. These open spaces on the hill sides are known as glades (Foerst 1903 *in* Guthrie 1989).

The Moulton and Tennessee Valley Limestone Hill Barrens of the Western Pennyroyal Karst Plain of Tennessee likely experience similar threats as other glades, but due to their occurrence away from a major population center the scale is far less and almost non-existent at most sites. However, some examples of this community have been adversely impacted from exotic species from nearby developments and conversion of surrounding hardwood forests to pine plantations (TNHP 2011).

Even without degradation or destruction, few examples of this community occur on Tennessee's landscape and few have been protected. Currently, the largest protected site occurs within the 101-ha Carroll Cabin Barrens State Natural Area and a few small patches occur within Mousetail Landing State Park. The Tennessee Division of Natural Areas knows of another high-quality site, but currently it remains unprotected. Based on satellite imagery a few larger glades exist near Mousetail Landing State Park, but they've yet to be inventoried.

Pennyroyal Karst Plain Subsection (223Eh)
Tennessee: 633,102 ha
Kentucky: 587,164 ha

In Kentucky, although the Pennyroyal Karst Plain is known for both historic and remnant grasslands or barrens, the barrens within this subsection contain deep, often fertile soils

contrasted with rocky barrens associated with glades (Chester et al. 1997). Pennyroyal Karst Plain Prairie and Barrens (CES202.355) is one such community, as is Western Highland Rim Prairie and Barrens (CES202.352). The later sometimes occurs along the watershed divide between the Tennessee and Cumberland Rivers, and although it occurs atop gravel soils of chert, it does not qualify as a glade because it lacks the presence of shallow soil over nearly solid bedrock substrate.

In Kentucky, only one limestone flatrock glade is known to occur in this subsection, occurring over Ste. Genevieve Limestone. This site is 40 ha and is protected as Flat Rock Glade State Nature Preserve, including the largest and highest quality limestone flatrock glade in Kentucky (KSNPC 2012). This southern Kentucky glade is a disjunct part of the Nashville Basin Limestone Glade and Woodland (CES202.334) system (NatureServe 2011).

Total area mapped: In Kentucky, this subsection contains one mapped limestone flatrock glade totaling 1.2 ha (KSNPC 2012).

Note: A small but high-quality limestone slope glade (~ .40 ha) also occurs at Woodburn Glade State Nature Preserve but has not been mapped in the KSNPC Heritage Database (Quinlan et al. 2002).

Glade area under protection: (KY ONLY DATA)

Federal: None State: KSNPC: 1.6 ha TNC: None Other NGOs: None

Plant and animal species of conservation concern: In Kentucky, Flat Rock Glade State Nature Preserve protects populations of 8 of the 25 rare glade-associated species in this subsection, with 2 of them state-endangered. Nearby, Woodburn Glade State Nature Preserve protects populations of 6 of the 25 rare glade-associated species, including Gattinger's lobelia (*Lobelia appendiculata* var. *gattingeri)* (S1)*,* the only known population in the state (Quinlan et al. 2002).

The following is a list of rare Kentucky glade plants that occur in this subsection (extant or historic) (KSNPC 2012):

Glade Obligate or Optimal: Side-oats grama (*Bouteloua curtipendula*)*,* Carolina larkspur (*Delphinium carolinianum*)*,* wedge-leaved whitlow grass (*Draba cuneifolia*), upland privot (*Forestiera ligustrina*)*,* Butler's quillwort (*Isoetes butleri*),necklace gladecress (*Leavenworthia torulosa), slender blazing-star (Liatris cylindracea*)*,* Gattinger's lobelia (*Lobelia appendiculata* var. *gattingeri),* yellow false mallow (*Malvastrum hispidum*)*,* Thread-leaf sundrops (*Oenothera linifolia*)*,* stemless evening primrose (*Oenothera triloba*)*,* barren's silky aster (*Symphyotrichum* pretense), limestone fameflower (*Talinum calcaricum*)*.*

Glade Suitable or Marginal: Plains frostweed (*Helianthemum bicknellii*), Eggert's sunflower (*Helianthus eggertii*), hairy hawkweed (*Hieracium longipilum*), Plains muhlenbergia (*Muhlenbergia cuspidata*), hair grass (*Muhlenbergia glabrifloris*), eastern eulopus (*Perideridia Americana*), *rough rattlesnake* (*Prenanthes aspera*), tansy rosinweed (*Silphium pinnatifidum*), rough dropseed (*Sporobolus clandestinus*), western heath aster (*Symphyotrichum priceae*), narrowleaf bluecurls (*Trichostema setaceum*), buffalo clover (*Trifolium reflexum*).

Southern Cumberland Plateau Section (231C) (2,347,997 ha in Alabama):

Moulton Valley Subsection (231Ce)
Alabama: 102,113 ha

Scattered across northern Alabama, the Moulton and Tennessee Valley Limestone Hill Barrens occur as an unusual and intriguing series of naturally exposed rock outcrops known as limestone glades. These glades have captured the attention of scientists and conservationists since the beginning of the state's biological studies in the early 1800s. These outcrops eloquently illustrate the impact of bedrock geology on plants, being well distinguished from adjacent plant associations by exposed areas of rock pavement, gravel, and/or shallow soil that sustain a remarkably diverse yet delicate assemblage of plant and animal life not found elsewhere in the state. Woody species are often sparse, being primarily restricted to crevices and peripheral areas where sufficient soil has accumulated to sustain growth. Herbaceous vegetation assumes prominence, including many endemics. In fact, endemism is the hallmark of these specialized edaphic habitats, containing some of the most critically imperiled and restricted plant life in North America. In their species inventory lists, the Alabama Natural Heritage Program recognizes 18 globally threatened and endangered taxa occurring in the limestone glade systems of Alabama.

In their classic paper describing the floristics of 5 limestone barrens in northwest Alabama, Webb, DeSelm, and Dennis (1997) list 265 predominantly native vascular plants, including 183 dicots, 77 monocots, 4 gymnosperms, and 1 fern, distributed among 164 genera and 62 families. Three families, the Asteraceae, Poaceae, and Fabaceae, however, constitute a significant proportion of the vegetation, representing 46% of the flora. While the purpose of the paper was not to cover the full spectrum of plant life to inhabit limestone barrens and glades (barrens consist of 50% or more perennial grass cover, glades less than 50%), it does furnish a good assessment of the floristic elements expected for these habitats across the northernmost section of Alabama.

Woody vegetation attains its greatest development on glade margins and crevices where soils have accumulated sufficient depth (Webb et al. and field observations). In the absence of a well-defined canopy, a dense layer of small trees and shrubs, often twisted and stunted in nature,

assume prominence. Eastern red cedar (*Juniperus virginiana* var. *virginiana*) stands out as the most conspicuous; however, chinquapin oak (*Quercus muehlenbergii*), Shumard oak (*Quercus shumardii*), white ash (*Fraxinus americana*), winged elm (*Ulmus alata*), and persimmon (*Diospyros virginiana*) are also common. Important smaller trees and shrubs include redbud (*Cercis canadensis*), aromatic sumac (*Rhus aromatica*), upland privet (*Forestiera ligustrina*), Drummond's dogwood (*Cornus drummondii*), dwarf hackberry (*Celtis tenuifolia*), and Carolina buckthorn (*Frangula caroliniana*).

Apart from bare rock, areas not densely covered by shrubs support a diverse herbaceous flora. More than 275 indigenous herbaceous species have been recorded in this habitat. Several of these species are mostly limited to the limestone glades and barrens communities. Examples of herbaceous species restricted to glades and barrens and commonly found in this habitat in north Alabama include Butler's quillwort (*Isoetes butleri*), Alabama glade cress (*Leavenworthia alabamica*), Gattinger prairie-clover (*Dalea gattingeri*), southern scurfpea (*Pediomelum subacaule*), Texas stonecrop (*Sedum pulchellum*), Eggleston's violet (*Viola egglestonii*), and glade beardtongue (*Penstemon tenuiflorus*). While glade beardtongue is equally at home in the Black Belt prairies further south, the majority of herbaceous flora consists of grassland species more cosmopolitan in distribution across the eastern United States. Grasses are dominant--most notably blankets of broomsedges (*Andropogon virginicus* and to a lesser extent, *Andropogon gerardii*) and little bluestem (*Schizachyrium scoparium*). Where soils are generally too shallow for the above-mentioned grass species, sheathed dropseed (*Sporobolus vaginiflorus*), old witch panicgrass (*Panicum capillare*), and slightly more localized in distribution, wiry witchgrass (*Panicum flexile*) occur. Taxa belonging to the Asteraceae and Fabaceae families are also well represented. Among the more noteworthy are narrowleaf gumweed (*Grindelia lanceolata*), daisy fleabane (*Erigeron strigosus*), sneezeweed (*Helenium autumnale*), hairy sunflower (*Helianthus hirsutus*), scaly gayfeather (*Liatris squarrosa*), gray goldenrod (*Solidago nemoralis*), bushy aster (*Symphyotrichum dumosum*), spreading aster (*Symphyotrichum patens*), partridge pea (*Chamaecrista fasciculata*), white prairie-clover (*Dalea candida*), small-leaf tick-trefoil (*Desmodium ciliare*), and Virginia bush-clover (*Lespedeza virginica*). Other common and characteristic species include false garlic (*Nothoscordum bivalve*), prairie-tea (*Croton monanthogynus*), roundfruit St. John's-wort (*Hypericum sphaerocarpum*), hairy wild petunia (*Ruellia humilis*), slender heliotrope (*Heliotropium tenellum*), false pennyroyal (*Trichostema brachiatum*), narrowleaf vervain (*Verbena simplex*), and the two succulents false aloe (*Manfreda virginica*) and Eastern pricklypear (*Opuntia humifusa*).

Sandstone Mountain Subsection (231Cd)

Alabama: 595,120 ha

Tennessee: 52,920 ha

Interior Low Plateau: Transition Hills Section (223B)
1,414,938 ha total in Indiana and Kentucky

This distinctive biogeographic region, lying between the Bluegrass Section to the east and the Shawnee Hills Section to the west, includes part of southern Indiana and part of west central Kentucky. Differences in landform, soils and vegetation produce three ecological subsections in the Transition Hills of Kentucky and three subsections in Indiana (McNab et al. 1994). The subsections are characterized by or differentiated as broad karst plains of Mississippian age, an expanse of steep, deeply-dissected hills (some hills conical-shaped into distinctive knobs) of Mississippian and Devonian ages (Kentucky), and areas of rugged, dissected uplands also of Mississippian age (Indiana-Brown County Hills).

In general, glades in the Transition Hills of Kentucky occur most abundantly within the Western Knobs Subsection where Devonian and Mississippian age rocks support both siltstone/shale and limestone glades. These glades are part of two ecological systems as defined by NatureServe (2011): the Central Interior Highlands Dry Acidic Glade and Barrens (CES202.692) and the Central Interior Highlands Calcareous Glade and Barrens (CES202.691). Within the Knobs, glades are (as in other parts of Kentucky) small in size, south to west-facing and thinly scattered on usually moderate slopes (KSNPC 2012). The Mitchell Karst Plains of Kentucky support good development of limestone glades, most often along the hillier margins of the karst plain (KSNPC 2012).

Glade Associations

Kentucky State Nature Preserves Commission (KSNPC) updated their *Kentucky Natural Communities* classification in 2009 and delineated 6 types of Kentucky glades based on parent material and topographical position (KSNPC 2009). Over the past 20 years, the *Kentucky Natural Communities* classification and subsequent community discussions (lead by several state ecologists) with NatureServe have become the basis for describing the NatureServe glade associations.

KSNPC (2009) described 6 glade natural communities with only 2 of these found in the Transition Hills Section. These are shown below with the equivalent NatureServe Association:

KSNPC (2009)		**NatureServe (2011)**
Limestone slope glade	=	Central Limestone Glade
	&	Kentucky Glade Seep
Shale/siltstone glade	=	Central Shale Glade
	&	Kentucky Knobs Shale Barren (in part)

Homoya (1994) described Indiana glade communities as barrens with principal bedrock types of limestone, sandstone, and siltstone. Equivalent NatureServe (2011) descriptions for these communities are Central Limestone Glade at limestone sites, Shawnee Sandstone Glade for sandstone, and Central Shale Glade in siltstone bedrock. Homoya described other similar communities in Indiana that are restricted to the Mitchell Karst Plain as chert barrens or in NatureServe referred to as Post Oak Chert Barrens.

Brown County Hills Subsection (223Ba)
Indiana: 252,941 ha

Based on data from the Indiana Department of Natural Resources Indiana Natural Heritage Data Center, this subsection does not contain any known glade communities (IDNR 2012).

Brush Creek Hills Subsection (223Bb)
Kentucky: 42,666 ha

This subsection, completely within Kentucky, is a relatively small band of hills lying between the Mitchell Karst Plains to the north and the Pennyroyal Karst Plains to the south (McNab et al. 1994). This hilly region is dominated by sandstone and limestone bedrock but potential for glades to occur is low. To date, community inventories conducted throughout most of the area have shown no known glade occurrences (KSNPC 2011).

Mitchell Karst Plains Subsection (223Bc)
Indiana: 437,345 ha
Kentucky: 205,781 ha

The Mitchell Karst Plains is a large rolling plain similar to the Pennyroyal Plain of southern Kentucky and north central Tennessee and includes slightly hilly topography along the boundary margins (Quarterman and Powell 1978). Mississippian age limestones are most prevalent and include numerous sinkhole features. Historically much of the area in Kentucky was native grassland-prairie--a northern extension of the Pennyroyal Karst Plain Prairie and Barrens (CES202.355) system (Evans and Abernathy 2008, Natureserve 2011). Today, cropland and pastures dominate the plains with few significant natural areas remaining (KDGI 2004, KNSPC 2012).

This subsection occurs in both Kentucky and Indiana and includes a significant portion of state-special concern (S3) limestone slope glades in Kentucky. Most of the existing glades in Kentucky are found on Salem Limestone of Mississippian age and could actually be considered part of the Western Knobs Subsection instead of the Mitchell Karst Plains (Woods et al. 2002 vs. McNab et al. 1994). Currently some of the best examples of limestone slope glades are found in

this area. Two of these are protected by the Kentucky State Nature Preserves Commission--Thompson Creek Glades State Nature Preserve and Jim Scudder State Nature Preserve--while other important glades are found along Cedar Creek in Hardin County (which are partly owned by U. S. Army at Fort Knox and partly privately owned. See additional information in the Western Knobs Subsection). Community descriptions are provided in the report Kentucky Natural Communities (KSNPC 2009) and include dominant, characteristic, and restricted species.

Number of known glades and total area mapped: The subsection contains 8 mapped limestone slope glades totaling 29 ha.

Glade area under protection:

Federal: U.S. Army: ~5.7 ha State: KSNPC: 6 ha TNC: ~.81 ha (pending) Other NGOs: None (Note: TNC is in the process of acquiring a small glade (Hardin Cedar Glade: ~.81 ha) from a private landowner.)

Plant and animal species of conservation concern: Barrens silky aster *(Symphyotrichum pratense)* is a unique glade species with limited distribution throughout the southeastern US. It is listed as critically imperiled (S1) in 5 of these states (Naturserve 2012), although the Natural Heritage global rank, G4?, indicates its status is considered relatively secure. In Kentucky there are 25 known occurrences of barrens silky aster with some populations healthy and stable and thus listed as state-special concern (S3) (KSNPC 2012). Considering these are the northernmost populations and that adjacent southern states list it as critically imperiled, further steps should be taken to secure the populations in Kentucky.

The following is a list of rare Kentucky glade plants in this subsection (extant or historic), excluding sensitive species (KSNPC 2012):

Glade Obligate or Optimal: Crawe's sedge (*Carex crawei*), scarlet Indian paintbrush (*Castilleja coccinea*), purple prairie-clover (*Dalea purpurea*), wedge-leaved whitlow-grass (*Draba cuneifolia*), slender blazing-star (*Liatris cylindracea*), thread-leaf sundrops (*Oenothera linifolia*), few-flowerd scurf-pea (*Psoralidium tenuiflorum*), Great Plains ladies'- tresses (*Spiranthes magnicamporum*), barrens silky aster (*Symphyotrichum pratense*), Eggleston's violet (*Viola egglestonii*).

Glade Suitable or Marginal*: Prairie gentian (Gentiana puberulenta*), broadleaf beardgrass (*Gymnopogon ambiguus*), Eggert's sunflower (*Helianthus eggertii*), hairy hawkweed (*Hieracium longipilum*), rough rattlesnake-root (*Prenanthes aspera*), and tansy rosinweed (*Silphium pinnatifidum*).

In this subsection, most of the original glades are thought to have been removed or are declining as a result of change from the original, natural landscape to an agricultural one (KDGI 2004, KSNPC 2012) . Today, housing developments continue to encroach on remaining natural landscapes (often the hilly regions) causing further fragmentation of natural communities,

including glades. From recent notes taken during surveys in the area, most impacts to and loss of glades is from road building, land clearing for housing developments, and logging.

The Indiana portions of this subsection contain scattered limestone or siltstone glades and chert barrens ranging in size from less than .40 ha to larger sites of 14 ha (IDNR 2012). Limestone glades are the most prevalent and widespread community type in the subsection with 18 documented areas. Most limestone sites are near the Ohio River, but a few areas occur to the north as far as Spring Mill State Park in Lawrence County. Limestone glades comprise about 24 ha, of which 6 ha are in Indiana state properties and 9 ha occur in lands owned by The Nature Conservancy (IDNR 2012). Generally, these limestone glades are small remnant sites with most areas documented as ranging from .80 – 1.2 ha. Homoya (1994) describes these limestone communities as occurring mostly on steep, south-facing slopes where the soil is neutral to alkaline and shallow in depth.

Known siltstone glades exist in the subsection from 8 sites that occur primarily in locales in counties bordering the Ohio River. Known siltstone glades total about 8 ha. Three of these sites, totaling 5 ha, are under protection, with 2 sites in Indiana state nature preserves and another in a TNC property. Chert barrens occur at 6 sites with 5 locales scattered throughout Harrison County that borders on the Ohio River and 1 other site further north in Washington County. These documented chert barrens are about 33 total ha, with 10 ha protected in Indiana state nature preserves (IDNR 2012).

Indiana area under protection:

Federal: none State: 21 ha TNC: 9 ha

Indiana plant and animal species of conservation concern: Several state endangered and threatened species occur in glades and barrens in the subsection. Indiana state critically imperiled (S1) plant species inhabiting limestone and siltstone glades or chert barrens include glade spikerush (*Eleocharis bifida*), nondo lovage (*Ligusticum canadense*), long-awn hairgrass (*Muhlenbergia capillaris*), pink milkwort (*Polygala incarnata*), and Eggleston's violet (*Viola egglestonii*) (IDNR 2012). Notable state threatened insects found in these areas are mottled duskywing (*Erynnis martialis*), multicolored huckleberry moth (*Pangrapta decoralis*), and red-striped panic grass moth (*Tampa dimediatella*). The state endangered (SE) southeastern crowned snake (*Tantilla coronate*) occurs within the Indiana State Sherman Minton Nature Preserve (IDNR 2010, 2012). Additionally, several other state endangered plants occur in nearby non-glade habitat at these sites.

Indiana threatened (S2) Glade Obligate: Crawe's sedge (*Carex crawei*), downy gentian (*Gentiana puberulenta*), and slender heliotrope (*Heliotropium tenellum*).

Other Glade Obligate or Optimal: straggling St. John's-wort (*Hypericum dolabriforme*), grooved yellow flax (*Linum sulcatum*), limestone adder's tongue (*Ophioglossum engelmannii*) (RFSS), narrowleaf summer bluets (*Stenaria nigricans*), and golden Alexanders (*Zizia aptera*).

Western Knobs Subsection (223Bd)
Kentucky: 466,295 ha
Indiana: 9,910 ha

The Western Knobs Subsection, of which the majority (~98%) is within Kentucky, is a large, dissected area of hills often referred to as Muldraugh Hill (with the entire knobs region often referred to as the Knobstone Escarpment) (Quarterman and Powell 1978). The northern part of this subsection is a distinctive landscape due to low, rolling plains of the Bluegrass to east and north, and the low Mitchell Karst Plains to the west (Braun 1950). The "escarpment consists of steep slopes developed primarily on shales, siltstones and sandstones of the Borden Formation" (Quarterman and Powell 1978). Lower slopes and valleys also include Mississippian age limestones, Devonian age shales and Silurian age dolomites. Today, most of the Western Knobs Subsection is forested (KDGI 2004).

This subsection is the primary range for Kentucky's shale/siltstone glades (S2S3), with most of the existing shale/siltstone glades found along moderate to steep south to west-facing slopes of the Borden formation (Mississippian age) (KSNPC 2012). All of these glades lack conservation protection but they are also less diverse than all other glades in Kentucky (KSNPC 2009).

Limestone slope glades in this subsection primarily develop on dry hillsides over Salem limestone and shales and over dolomites of the Osgood Formation, but a few are also found on the Borden Formation (KSNPC 2012, KGS 2004). The limestone glades along Cedar Creek in Hardin County (which are partly owned by U. S. Army at Fort Knox and partly privately owned) are the largest intact complex known in Kentucky, and current initiatives to protect the site are ongoing. This site lies partly in this subsection and partly in the Mitchell Karst Plains (Note: an argument can be made that the glade complex at Cedar Creek should be wholly included in the Western Knobs Subsection) (McNab et al. 1994 vs. Woods et al. 2002). Other glade sites have received conservation attention in recent years but due to limited planning and lack of landowner cooperation, conservation efforts have been mostly unsuccessful. Community descriptions are provided in the report: Kentucky Natural Communities (KSNPC 2009) and include dominant, characteristic, and restricted species.

Total area mapped: The subsection contains 13 mapped glades: 6 limestone slope glades totaling approximately 16 ha and 7 shale/siltstone glades totaling approximately 16 ha. KSNPC believes only a portion of the existing shale/siltstone glades in this subsection have been mapped due to the community being of lesser conservation priority. Further surveys are needed, and additional occurrences are expected (KSNPC 2012).

Glade area under protection:

Federal: U.S. Army: ~2.8 ha State: None TNC: None Other NGOs: None

Plant and animal species of conservation concern: In Kentucky, purple prairie-clover (*Dalea purpurea*) is listed as state-special concern (S3), with only 18 populations known to occur. Fourteen of these occur in glades within Hardin and Nelson Counties of this subsection. The other 4 are found among a few limestone glades of the Southern Dripping Springs in Logan County (KSNPC 2012). Within the Western Knobs, only 1 of the 14 populations is found on a conservation land (Fort Knox Military Base).

The following is a list of rare Kentucky glade plants in this subsection (extant or historic), excluding sensitive species (KSNPC 2012):

Glade Obligate or Optimal: Side-oats grama (*Bouteloua curtipendula*), Crawe's sedge (*Carex crawei*), purple praire-clover (*Dalea purpurea*), hairy fimbristylis (*Fimbristylis puberula*), Plains rush (*Juncus filipendulus*), Kentucky glade-cress (*Leavenworthia exigua* var. *laciniata*), stemless evening primrose (*Oenothera triloba*), barrens silky aster (*Symphyotrichum pratense*), and *Eggleston's violet (Viola egglestonii)*.

Glade Suitable or Marginal: Tansy rosinweed (*Silphium pinnatifidum*), prairie dropseed *(Sporobolus heterolepis*) and narrowleaf bluecurls (*Trichostema setaceum*.)

Threats to glades in the subsection: In this subsection, a significant portion of the original glades are thought to still exist on the landscape due to their occurrence in hilly, forested areas with poor soils (KDGI 2004, KSNPC 2012). Though steady declines in quality are due to continual human disturbance since Euro-American settlement (e.g., grazing, logging, ATVs, etc.). Today, housing developments continue into the forested hills causing further fragmentation of natural communities, including glades. From recent notes taken during surveys in the area, major impacts to and loss of glades comes from road building, land clearing for housing developments, and logging.

The Indiana portion of this subsection contains only a few documented glade communities of limestone and siltstone that occur along the Ohio River in Harrison and Floyd counties. The Harrison county site is a small limestone glade of 2.1 ha, which occurs within the Indiana State Teeple Glade Nature Preserve. The Floyd county site is a complex of several small siltstone glades ranging in size from about .68-1 ha. All of the siltstone glades are within the Indiana State Brock Sampson Nature Preserve and total about 3.6 ha (IDNR 2012).

Indiana area under protection:

Federal: none State: 5.7 ha TNC: none

Indiana plant and animal species of conservation concern: No state endangered and threatened plant species occur in glades and barrens in the subsection. Slender-stalked gaura (*Gaura filipes*)

is a state threatened (ST) species that inhabits open woods occurs nearby in the Teeple Glade Nature Preserve (IDNR 2012). The state endangered (SE) southeastern crowned snake (*Tantilla coronata*) occurs within the Brock Sampson Nature Preserve.

Glade Obligate or Optimal: straggling St. John's-wort (*Hypericum dolabriforme*), grooved yellow flax (*Linum sulcatum*), limestone adder's tongue (*Ophioglossum engelmannii*) (RFSS), narrowleaf summer bluets (*Stenaria nigricans*), and golden Alexanders (*Zizia aptera*).

Interior Low Plateau: Shawnee Hills Section (223D)

(3,523,599 ha total in Illinois, Kentucky and Indiana):

This distinctive biogeographic region of western central Kentucky, southern Indiana, and the southernmost section of Illinois is a structural basin of variably aged carboniferous sedimentary rock strata dominated by Late Mississippian and Pennsylvanian Ages (Quarterman and Powell 1978). The section consists of an expanse of hills and ridges, which contrast with broad alluvial and lacustrine stream valleys of the Green, Tradewater, Cumberland, Ohio, Wabash, and Cache Rivers and some of their tributaries (Quarterman and Powell 1978). Differences in landform, soils, and vegetation produce 7 ecological subsections in the Shawnee Hills part of Kentucky, 2 subsections in parts of Illinois and 4 subsections in parts of Indiana (McNab et al. 1994).

The hills and ridges portion supports development of sandstone and limestone glades on usually gradual to moderate slopes. These glades are part of 2 ecological systems as defined by NatureServe (2011): the Central Interior Highlands Dry Acidic Glade and Barrens (CES202.692) and the Central Interior Highlands Calcareous Glade and Barrens (CES202.691). Glades or similar rocky formations are thinly distributed across the entire section, with a few subsections completely lacking glade development (KSNPC 2012). Glades in the Shawnee Hills of Kentucky occur more abundantly within the Southern and Northern Dripping Springs Subsection (KSNPC 2012, McNab et al. 1994).

Glade Associations

Kentucky State Nature Preserves Commission (KSNPC) in 2009 updated their *Kentucky Natural Communities* classification and delineated 6 types of Kentucky glades based on parent material and topographical position. Over the past 20 years, the *Kentucky Natural Communities* classification and subsequent community discussions (lead by several State ecologists) with NatureServe have become the basis for describing the NatureServe glade associations.

KSNPC (2009) described 6 glade natural communities with only three of these found in the Shawnee Hills Section. These are shown below with the equivalent NatureServe Association:

KSNPC (2009)		NatureServe
Shawnee Hills sandstone glade	=	Shawnee Sandstone Glade
Limestone slope glade	=	Central Limestone Glade
	&	Kentucky Glade Seep
Limestone flatrock glade	=	Limestone Annual Grass Glade
	&	Central Basin Limestone Glade Margin Shrubland
	&	Interior Low Plateau Limestone Glade Ephemeral

Interior Western Coalfields Subsection (223Da)
Kentucky: 333,796 ha

Glade occurrence is extremely rare in this subsection, and no occurrences are known.

Lower Ohio-Cache-Wabash Alluvial plains Subsection (223Db)
Kentucky: 142,757 ha
Indiana: 133,892 ha

Glade occurrence is extremely rare in this subsection, and no occurrences are known.

Outer Western Coalfields Subsection (223Dc)
Kentucky: 680,712 ha
Indiana: 305,222 ha

Glade occurrence is extremely rare in this subsection, and no occurrences are known.

Marion Hills Subsection (223Dd)
Kentucky: 98,562 ha

The Marion Hills is a uniquely developed hilly subsection "mostly on strata of Mississippian age that is broken by numerous faults such that the simple cuesta-form topography characteristic of the Interior Low Plateaus Province is not readily apparent" (Quarterman and Powell 1978). Today, the Marion Hills landscape has a fairly even distribution of forests, pastures, and cropland (KDGI 2004).

Glade types: This subsection is completely within Kentucky and includes the largest and best developed state-threatened (S1S2) Shawnee Hills sandstone glade in the state. The glade and adjacent sandstone arch, known as Mantle Rock, are significant components of a protected

Nature Conservancy Preserve, which is recognized as a certified site on the Trail of Tears National Historic Trail. Other sandstone glades may occur in this area as noted by past natural areas inventories, but these sites need further exploration (KSNPC 2011). Community descriptions are provided in the *Kentucky Natural Communities* (KSNPC 2009) and include dominant, characteristic, and restricted species.

Total area mapped: The subsection contains one mapped limestone slope glade totaling .40 ha and 1 mapped Shawnee Hills sandstone glade totaling 2.4 ha.

Glade area under protection:

Federal: None State: None TNC: 2.4 ha Other NGOs: None

Plant and animal species of conservation concern: Although no rare glade endemics are known to occur at Mantle Rock, small-flowered flameflower (*Talinum parviflorum*) is known from several counties in the adjacent Shawnee Hills of Illinois where it is state-endangered (S1) (NatureServe 2012). Potential for this species to occur in Kentucky is greatest in this subsection. The only occurrence of Prairie Junegrass (*Koeleria macrantha*) in Kentucky is found on the Mantle Rock Preserve but is currently considered a dry woodland/barrens species (KSNPC 2012). Future restoration efforts to open forests and woodlands surrounding glades should consider how management can benefit this species.

The following is a list of rare glade plants in this subsection (extant or historic) (KSNPC 2012):

Glade Obligate or Optimal: Hairy fimbristylis (*Fimbristylis puberula*), Great Plains ladies' tresses (*Spiranthes magnicamporum).*

Glade Suitable or Marginal: Western hairy rockcress (*Arabis hirsuta*), downy gentian (*Gentiana puberulenta*), broadleaf beardgrass (*Gymnopogon ambiguus*), hairy hawkweed (*Hieracium longipilum*), prairie junegrass (*Koeleria macrantha*), hair grass (*Muhlenbergia glabrifloris*), rough dropseed (*Sporobolus clandestinus*), prairie dropseed (*Sporobolus heterolepis*), Buffalo clover (*Trifolium reflexum).*

Threats to glades in the subsection: Only 2 glades are mapped in this subsection but a section of McGilligan Creek, along the boundary of Mantle Rock Nature Preserve in Livingston County, Kentucky, has well developed and level sandstone outcrops and small depression pools (KSNPC 2011). Because the creek is adjacent to a paved road, human use of the area is intense, with encroachment from houses just above the creek and disturbance from recreational activity (e.g., swim or picnic area, foot paths, ATV trails, etc.). Many of the dry ledges contain invasive Japanese stiltgrass (*Microstegium vimineum*) and other weeds (KSNPC 2011). Original vegetation and community development might have been similar to the high quality sandstone

glade at Mantle Rock Nature Preserve. A similar disturbance history is expected in other areas of this subsection.

Crawford Uplands Subsection (223De)
Indiana: 464,659 ha
Kentucky: 14,958 ha

The Indiana portions of this subsection contain scattered limestone glades and sandstone glades in Crawford and Perry Counties that border the Ohio River. Other sandstone glades exist in Martin County at 4 small, scattered rocky ridgetops near Shoals, Indiana. The entire glade habitat known on the Hoosier National Forest occurs in this subsection. Limestone glades are more common community type in the subsection with 11 documented sites, most of which occur in protected Hoosier National Forest Special Areas. The sandstone glades are about 9 ha and limestone glades are 34 ha, for a total of 43 ha of known sites in Indiana (IDNR 2012). Several species listed by Indiana State as either endangered or threatened are of conservation concern that inhabits glades on the Hoosier National Forest. The Forest Service has designated the species most at risk as Regional Forester Sensitive Species (RFSS).

Indiana area under protection:

Federal: 16,446 ha	State: 5.7 ha	TNC: Boone Creek Barrens site – 16 ha (unknown quantity of glade habitat)

Indiana plant and animal species of conservation concern: Several state endangered and threatened species occur in glades in the subsection. Two known Indiana state endangered critically imperiled (S1) plant species inhabiting limestone glades are prairie parsley (*Polytaenia nuttallii*) (RFSS), a glade optimal species, and buffalo clover (*Trifolium reflexum*) (RFSS), a glade suitable species. Both of these plants occur in the Boone Creek Special Area on the Hoosier National Forest (IDNR 2012). Other state endangered (S1) plants on the Hoosier National Forest with known populations are bluehearts (*Buchnera americana*) (RFSS), which occur in a small limestone glade remnant next to an old field in the Clover Lick Special Area, and Porter's reedgrass (*Calamagrostis porteri* ssp. *porteri*) (RFSS), which occurs near a sandstone glade in the Plaster Creek Special Area.

State endangered (S1) critically imperiled species included in the subsection within these glades are Kansas prairie leafhopper (*Prairiana kansana*) (RFSS) and Jaguar flower moth (*Schinia jaguarina*) (RFSS). Other notable state threatened insects found in limestone glades are Bell's roadside skipper (*Amblyscirtes belli*), dusted skipper (*Atrytonopsis hianna*) (RFSS), swamp metalmark (*Calephelis muticum*) (RFSS), mottled duskywing (*Erynnis martialis*) (RFSS), Indian grass flexamia (*Flexamia reflexus*) (RFSS), Beer's blazingstar borer moth (*Papaipema beeriana*) (RFSS), prairie panic grass leafhopper (*Polyamia herbida*) (RFSS), and red-striped panic grass moth (*Tampa dimediatella*) (IDNR 2010, 2012). Additionally, several other state rare insects

occur in glades habitat on the Hoosier National Forest in the Boone Creek, Clover Lick, and Harding Flats Special Areas (Bess 2005). Many of these insects, as well as most all state threatened species, are RFSS for the Hoosier National Forest.

Indiana threatened (S2) Glade Optimal: Cluster fescue (*Festuca paradoxa*) (RFSS).

Other Glade Obligate or Optimal: Yellow gentian (*Gentiana alba*) (RFSS), grooved yellow flax (*Linum sulcatum*), limestone adder's tongue (*Ophioglossum engelmannii*) (RFSS), rough rattlesnake-root (*Prenanthes aspera*), and golden Alexanders (*Zizia aptera*).

Threats to glades in the subsection: The continued spread of non-native invasive plants and woody encroachment because of the lack of active management are the primary threats to glade habitat on the Hoosier National Forest. Japanese stiltgrass (*Microstegium vimineum*), a non-native invasive plant, is prevalent along riparian areas, trails, old roads, and other disturbed ground. Other exotic species occurring near glades in smaller infestations include sericea lespedeza (*Lespedeza cuneata*), yellow sweet clover (*Melilotus officinale*), crown vetch (*Securigera varia*), Johnson grass (*Sorghum halepense*), multiflora rose (*Rosa multiflora*), and autumn olive (*Elaeagnus umbellata*).

Protection and Management: The Forest Service began to implement prescribed burning projects in glade (barrens) habitat in the Boone Creek Special Area in 1990 and 1991 after years of fire suppression. Subsequent landscape prescribed burn projects followed in 1992 and 1994. Similar projects occurred in the early 1990s in glades in the Clover Lick Special Area. Periodic burn projects have occurred in these designated special areas in fire-interval cycles of about 3-7 years, including a recent project done in November 2012. This management has increased the sizes of remnant barrens by removing woody encroachment and stimulated the expansion of many plants typically inhabiting these areas.

Other active management done at these sites includes girdling and felling of previously planted conifer species, which are not native to the glades or the geographical area comprising the Hoosier National Forest. Since 2009, the primary focal area for non-native control treatments on the Forest using herbicides has occurred within these three special areas. The key target invasive plants receiving herbicide treatments are Japanese stiltgrass, autumn olive, sericea lespedeza, crown vetch, and yellow sweet clover.

Crawford Escarpment Subsection (223Df)

Indiana: 183,758 ha

All glades in the Indiana portion of this subsection occur in areas along the Ohio River in Harrison County and adjacent Crawford County. All of the sites are limestone glades, which total approximately 40 ha. Nine of the 11 known glades occur in 2 Indiana state nature preserves, and the other 2 sites are in Harrison-Crawford State Forest. The Post Oak Nature Preserve in Harrison County has three documented glades of 7.4 ha, and the Leavenworth Barrens Nature Preserve in Crawford County contains 6 limestone glades equaling about 25.7 ha (IDNR 2012).

Indiana area under protection:

Federal: none State: 33 ha TNC: none

Indiana plant and animal species of conservation concern: Several state endangered and threatened species occur in glades in the subsection. The only known Indiana state endangered critically imperiled (S1) plant species inhabiting limestone glades (Optimal species) is prairie parsley (*Polytaenia nuttallii*) (RFSS) (IDNR 2012). The state endangered (S1) critically imperiled species short-winged panic grass leafhopper (*Polyamia dilata*) occurs at the Leavenworth Barrens Nature Preserve site. Other notable state threatened insects found in limestone glades are dusted skipper (*Atrytonopsis hianna*), Indian grass flexamia (*Flexamia reflexus*), multicolored huckleberry moth (*Pangrapta decoralis*), prairie panic grass leafhopper (*Polyamia herbida*), and red-striped panic grass moth (*Tampa dimediatella*) (IDNR 2010, 2012). Additionally, several other state endangered plants occur in nearby non-glade habitat at these sites.

Indiana threatened (S2) Glade Obligate: Slender heliotrope (*Heliotropium tenellum*).

Other Glade Obligate or Optimal: Yellow gentian (*Gentiana alba*) (RFSS), straggling St. John's-wort (*Hypericum dolabriforme*), grooved yellow flax (*Linum sulcatum*), limestone adder's tongue (*Ophioglossum engelmannii*) (RFSS), narrowleaf summer bluets (*Stenaria nigricans*), and golden Alexanders (*Zizia aptera*).

Southern Dripping Springs Subsection (223Dg)
Kentucky: 427,181 ha

This subsection is completely within Kentucky and includes the presence of Mississippian age sedimentary bedrock throughout the area, with Pennsylvanian age sedimentary bedrock along the margins of the northern boundary (KGS 2004). The southern boundary of this subsection is the low but prominent Dripping Springs Escarpment. Today, the Southern Dripping Springs landscape has a fairly even distribution of forests, pastures and croplands, including the 20,638-ha forested tract of Mammoth Cave National Park (KDGI 2004).

Glade types: Glades occur throughout the subsection mostly where sandstone or limestone outcrop along gradual to steep, south- to west-facing slopes.

This subsection is the primary range for Kentucky's state-threatened (S1S2) Shawnee Hills sandstone glades, with a few also occurring in the Marion Hills and Northern Dripping Springs. All 5 existing glades are found on the Tradewater and Caseyville Formations of lower Pennsylvanian age. Currently, one hiqh-quality example is protected at Sunset Barrens Nature Preserve, owned by The Nature Conservancy. The remaining are smaller and less significant with a few degraded from various land use.

This subsection also includes several state-special concern (S3) limestone slope glades and 2 state-endangered (S1) limestone flatrock glades. Most of the existing limestone glades are found on the Girkin Formation or the Reelsville Limestone of Mississippian age. Currently 2 examples of limestone slope glades are protected on Logan County State Nature Preserve and Raymond Athey Barrens State Nature Preserve. Community descriptions are provided in the *Kentucky Natural Communities* (KSNPC 2009) and include dominant, characteristic and restricted species.

Total area mapped: The subsection contains 8 mapped limestone slope glades totaling 15 ha, 5 mapped Shawnee Hills sandstone glades totaling 4.2 ha, and 2 mapped limestone flatrock glades totaling 1.6 ha.

Glade area under protection:

Federal: None State: KSNPC: 4 ha TNC: 1.8 ha Other NGOs: None

Plant and animal species of conservation concern: A population of limestone fameflower (*Talinum calcaricum*), that was found on Logan County Glade State Nature Preserve in 1988, has declined over the last 10 years and was not found during botanical surveys in 2011. This is one of only two populations known in Kentucky. The other population is also declining (KSNPC 2011).

The Southern Dripping Springs Subsection contains the most glade obligate or optimal species of any subsection in Kentucky.

The following is a list of rare glade plants in this subsection (extant or historic), excluding regional forester sensitive species (KSNPC 2012):

Glade Obligate or Optimal: Blue wild indigo *(Baptisia australis* var. *minor),* side-oats grama *(Bouteloua curtipendula),* Crawe's sedge *(Carex crawei),* purple prairie-clover *(Dalea purpurea),* Carolina larkspur *(Delphinium carolinianum),* wedge-leaved whitlow-grass *(Draba cuneifolia),* hairy fimbristylis *(Fimbristylis puberula),* upland privot *(Forestiera ligustrina),* Butler's quillwort *(Isoetes butleri),* Plains rush *(Juncus filipendulus),* necklace gladecrest *(Leavenworthia torulosa),* slender blazing-star *(Liatris cylindracea),* yellow false mallow *(Malvastrum hispidum),* thread-leaf sundrops *(Oenothera linifolia),* stemless evening primrose *(Oenothera triloba),* barrrens silky aster *(Symphyotrichum pratense),* limestone fameflower *(Talinum calcaricum),* and Eggleston's violet *(Viola egglestonii)*.

Glade Suitable or Marginal: Western hairy rockcress (*Arabis hirsuta*), yellow gentian (*Gentiana alba*), downy gentian (*Gentiana puberulenta*), broadleaf beardgrass (*Gymnopogon ambiguus*), Plains frostweed (*Helianthemum bicknellii*), Eggert's sunflower (*Helianthus eggertii*), hairy hawkweed (*Hieracium longipilum*), Western dwarf-dandelion (*Krigia occidentalis*), hair grass (*Muhlenbergia glabrifloris*),hairy false gromwell (*Onosmodium molle ssp. Hispidissimum*), Eastern eulopus (*Perideridia americana*), rough rattlesnake-root (*Prenanthes aspera*), tansy

rosinweed (*Silphium pinnatifidum*), rough dropseed (*Sporobolus clandestinus*), Western heath aster (*Symphyotrichum priceae*), and buffalo clover (*Trifolium reflexum*) (RFSS).

Threats to glades in the subsection: Most glades are declining as a result of change from an agricultural landscape to a more suburban one, with remnant natural areas being eliminated as the landscape changes. In the Southern Dripping Springs**,** aerial surveys in 2010 showed a considerable loss and/or degradation of glade communities; many of these sites or communities previously were mapped in the Kentucky Natural Heritage Database as high quality. Most of the recent impacts were from road building, land clearing for housing developments, logging, and quarry mining (KSNPC 2012).

Greater Shawnee Hills Subsection (223Dh)
Illinois: 188,325 ha

The subsection averages about 16 km wide and crosses much of southern Illinois from near the mouth of the Wabash River at the Ohio River in the southeastern portion of the state to near the Mississippi River to the west. It is characterized by an escarpment of weather-resistant Pennsylvanian-aged sandstone formed by synclines and anticlines of the Caseyville formation (Schwegman et al. 1973; Nelson and Lumm 1987; Nelson et al. 1991). Oak and hickory dominated woodland remains relatively extensive in the region.

Glade types: The natural community classification utilized in Illinois (IDNR 2010, modified from White and Madany 1978) recognizes three glade types under the Bedrock community class: sandstone, limestone, and shale glade. Sandstone glade is the primary type found in the Greater Shawnee Hills Subsection. Glades are associated primarily with outcrops of the Pounds Sandstone Member of the Caseyville formation. Sandstone glades generally occur at the tops of cliffs and on steep upper slopes of escarpments where sandstone is exposed and soil is poorly developed. Aspects of glade communities primarily range in orientation from southeast to southwest.

Total area mapped: Only land of high-quality glade habitats and recognized by the Illinois Natural Areas Inventory (INAI) has been mapped in detail. Sandstone glades previously recognized by the INAI in this subsection unit total 29 ha and consist of 17 sites averaging 1.71 ha, occurring in 6 counties across the Greater Shawnee Hills subsection. The largest complex is the Todd Fink Natural Area, a local archipelago of glades totaling 6 ha. An additional 43 ha recently have been recommended by INAI field staff for inclusion to the list of natural areas but await final confirmation. This total is composed of 14 glades averaging 3.1 ha, including 2 sites measured at just over 10 ha each. These additions bring the total sandstone glade habitat to 72.4 ha. Sandstone glades often merge with barrens (e.g., CEGL002391), dry woodland, and sandstone cliff communities. Transition to barrens communities occurs with greater than 50%

overstory cover and to woodland communities where soil is better developed (IDNR 2010, p. 73).

Glade area under protection: The glade area recognized by the INAI is protected from state or federally sponsored development, but glades on private lands are not protected from private development. Some glades not included in the INAI are protected in a state park and in IDNR-owned and privately owned nature preserves. Some glades occurring on USFS land are protected in wilderness designation and other special management areas.

USFS: unknown; State: IDNR: unknown area (not all is delineated; some at Round Bluff Nature Preserve, Lusk Creek Canyon Nature Preserve, Ferne Clyffe State Park); TNC: None; Private: Spivey's Valley Glade.

Plant species of conservation concern: Obligate and optimal sandstone glade species include Meads milkweed (*Asclepias meadii),* Allegeny stonecrop (*Hylotelephium telephioides*), long-awn hairgrass (*Muhlenbergia capillaris*), false garlic (*Nothoscordum bivalve*), thread-leaf sundrops (*Oenothera linifolia*), large-flowered fameflower (*Talinum calycinum)*, and small-flowered fameflower (*Talinum parviflorum*). Suitable species include prairie junegrass (*Koeleria macrantha*), and deerberry (*Vaccinium stamineum).*

Barrens optimal species of conservation concern, including included here because of the close habitat association with sandstone glade, include Southern corydalis (*Corydalis micrantha* ssp. *Australis*), long-awn hairgrass (*Muhlenbergia capillaris*), false garlic (*Nothoscordum bivalve*), pink milkwort (*Polygala incarnata*) (RFSS), and wavyleaf aster (*Symphyotrichum undulatum)*. Barrens suitable-to-marginal species include prairie junegrass (*Koeleria macrantha*), Buckley's goldenrod (*Solidago buckleyi),* and Buffalo clover (*Trifolium reflexum).*

Threats to glades in the subsection: Off-road vehicle traffic, excessive foot traffic, horse trails, invasive species.

Research and monitoring efforts: Illinois Natural Areas Inventory update (http://www.inhs.illinois.edu/research/inai/)

Lesser Shawnee Hills Subsection (223Di)
Illinois: 167,544 ha
Kentucky: 27,545 ha

This subsection occurs south of the Greater Shawnee Hills Subsection and north of the Ohio River in southern Illinois. Bedrock exposed in this subsection includes Mississippian and Devonian-aged sedimentary bedrock, primarily limestone and shale with some local areas of sandstone included (Schwegman et al. 1973, Nelson et al. 1991).

Glade types: Glades primarily occur above south-facing outcrops and slopes along major river valleys (e.g., current and historic Ohio River valleys). Limestone and shale glades are known from the subsection. Surface soils in the region primarily are formed in Peoria Loess (Willman and Frye 1970) and glades are formed where the loess deposits are thin or eroded, with south and southwest-facing orientation (Kurz 1981). Glades are found on limestones and shales of the Chesterian series. Formations exposed in the region include Kinkaid limestone (Nelson et al. 1991). Most glades are found in the southeastern portion of the subsection (Kurz 1981).

Total area mapped: Kurz (1981) mapped 23 limestone glades in the southeastern portion of Illinois totaling 21.4 ha; 6 of these appear to fall in the Bottomland Section of the Coastal Plain Natural Division. Nine other limestone glades were mapped in southwestern Illinois outside the subsection. Of the 23 mapped glades in southeastern Illinois, with approximately 17 falling inside the Lesser Shawnee Hills Subsection, some border the Ohio River and others are more interior and found near the former channel of the Ohio River (including approximately 6 in the Coastal Plain Division). Fourteen limestone glades in the region qualified for the INAI; of these, 6 glades in the Lesser Shawnee Hills totaling 2.6 ha recently were determined to be degraded and were disqualified from the INAI primarily due to conversion to upland woodland or suppression of the ground-layer flora (e.g., mowing). Eight glades in the Lesser Shawnee Hills section, totaling 1.4 ha, were determined to still meet INAI criteria in a recent update (data still being processed).

Glade area under protection: The glade area currently recognized by the INAI, totaling 1.4 ha, falls under protection from state and federally sponsored development; however, glades on private lands are not protected from private development. Cave Creek Glade Nature Preserve includes 10 ha of dry woodland and limestone glade habitat. The glade itself is .3 ha, and is a mix of hill prairie and glade habitats. One source places this in the Coastal Plain Natural Division (IDNR Heritage database) while another (http://dnr.state.il.us/INPC/09/Area%209/Johnson/CaveCreekGlade/CaveCreekGlade.htm) places the glade in the Lesser Shawnee Hills. A refinement of the natural divisions based on physiographic features likely would confirm its placement in the Lesser Shawnee Hills section and subsection. All protected shale glades in the region fall within the Ozark Natural Division, outside of the Lesser Shawnee Hills section of the Shawnee Hills Natural Division. Another limestone glade protected in this region bordering the two natural divisions is found in the Heron Pond-Little Black Slough Nature Preserve.

Plant species of conservation concern: Obligate and optimal limestone glade species for the entire glade conservation assessment region in Illinois include wedge-leaved whitlow-grass (*Draba cuneifolia*), reticulate-seeded spurge (*Euphorbia spathulata*), yellow false mallow (*Malvastrum hispidum*), chitin wood (*Bumelia lanuginosa*), false garlic (*Nothoscordum bivalve*), and Missouri orange coneflower (*Rudbeckia missouriensis*). Species known from within the subsection include white prairie-clover (*Dalea candida*), angle pod (*Matelea obliqua*), low prickly pear (*Opuntia macrorhiza*), glade cleft phlox (*Phlox bifida* ssp. *stellaria*), *and* wavyleaf aster (*Symphyotrichum undulatum*). The following additional species are ranked as suitable for limestone glade habitat: black-edge sedge (*Carex nigromarginata),* narrowleaf puccoon

(*Lithospermum incisum*), and plains muhlenbergia (*Muhlenbergia cuspidata*), In addition, the following species are known from within the subsection: Groove-stem Indian-plantain (*Arnoglossum plantagineum*), slender blazing star (*Liatris cylindracea*), Western false gromwell (*Onosmodium molle* ssp. *Occidentale*), rough rattlesnake-root (*Prenanthes aspera*), blue sage (*Salvia azurea* var. *grandiflora),* and Buckley's goldenrod (*Solidago buckleyi*).

Threats to glades in the subsection: Quarrying and woody encroachment due to fire absence are two major threats to limestone glade habitat.

Research and monitoring efforts: Illinois Natural Areas Inventory update (http://www.inhs.illinois.edu/research/inai/). A floristic analysis was completed based on the original INAI (Kurz 1981).

Northern Dripping Springs Subsection (223Dj)
Kentucky: 331,966 ha

This subsection is completely within Kentucky and includes the presence of Mississippian age sedimentary bedrock throughout the area, with Pennsylvanian age sedimentary bedrock along the margins of the western boundary (KGS 2004). Today, the Northern Dripping Springs landscape is heavily forested along the northern parts of the subsection as well as in areas surrounding large reservoirs (e.g., Nolin River reservoir), with remaining southern areas mostly in pasture (KDGI 2004).

Glade types: Glades occur mostly where sandstone or limestone outcrops along gradual to steep, south- to west-facing slopes. Community descriptions are provided in the *Kentucky Natural Communities* (KSNPC 2009) and include dominant, characteristic, and restricted species.

The eastern side of this subsection has a high density of state-special concern (S3) limestone slope glades. Most of the existing glades are found on the Beaver Bend Limestone, Glen Dean Limestone, Paoli Limestone, or Reelsville Limestone of Mississippian age. Currently one example of a limestone slope glade is protected on Springhouse Barrens State Nature Preserve. A large site in Meade County (with glades and barren remnants) received considerable conservation attention in recent years, but due to a change in landowner's interest to protect the site, conservation efforts were left unsuccessful.

Total area mapped: The subsection contains 12 mapped limestone slope glades totaling 42.5 ha, 1 mapped Shawnee Hills sandstone glade totaling .50 ha, and one mapped limestone flatrock glade totaling .16 ha. This is the highest total slope glade count among all other subsections in Kentucky.

Glade area under protection:

USFS: None State: KSNPC: .61 ha TNC: None Other NGOs: None

Plant species of conservation concern: Once a federally listed species, the state-threatened (S2) Eggert's sunflower (*Helianthus eggertii*) occurs in dry to xeric woodlands, occasionally found associated with fire-suppressed cedar-hardwood thickets that surround glades (in Kentucky this species is most abundant in the Southern Dripping Springs Subsection but also occurs in the Northern Subsection). Kentucky's 2008 winter ice storm extensively thinned forest canopies, producing many canopy gaps across expansive areas. In recent years, several Eggert's sunflower populations were documented as having a positive, vigorous response to this natural disturbance (KSNPC 2011); thus future glade restoration efforts should consider this species where applicable.

The following is a list of rare glade plants in this subsection (extant or historic) (KSNPC 2012):

Glade Obligate or Optimal: Crawe's sedge (*Carex crawei*), rigid sedge (*Carex tetanica*), wedge-leaved whitlow-grass (*Draba cuneifolia*), hairy fimbristylis (*Fimbristylis puberula*), Plains rush (*Juncus filipendulus*), slender blazing star (*Liatris cylindracea*), thread-leaf sundrops (*Oenothera linifolia*), Great Plains ladies'- tresses (*Spiranthes magnicamporum*), barrens silky aster (*Symphyotrichum pratense*), Eggleston's violet (*Viola egglestonii*)

Glade Suitable or Marginal: downy gentian (*Gentiana puberulenta*), broadleaf beardgrass (*Gymnopogon ambiguus*), plains frostweed (*Helianthemum bicknellii*), Eggert's sunflower (*Helianthus eggertii*), hairy hawkweed (*Hieracium longipilum*), small sundrops (*Oenothera perennis*), rough rattlesnake-root (*Prenanthes aspera*), tansy rosinweed (*Silphium pinnatifidum*).

Animal species of conservation concern: Extant and historic populations of Henslow's Sparrow (*Ammodramus henslowii*), Lark Sparrow *(Chondestes grammacus)*, and Eastern Slender Glass Lizard (*Ophisaurus attenuatus longicaudus*)--rare fauna associated with native grasslands and glades--occur in the southwestern corner of Hardin County.

Interior Low Plateau: Bluegrass Section (223F)

(3,182,371 ha total in Kentucky, Indiana and Ohio):

This distinctive biogeographic region of north central Kentucky and southeasternmost Indiana is "an eroded structural dome developed on strata ranging in age from middle Ordovician to early Mississippian…The Blue Grass Section is somewhat a topographic basin or lowland in that it is rimmed on the east, south and west by the Knobstone Escarpment, but it is actually a subdued cuesta-form upland plateau dissected by several deeply entrenched major streams." (Quarterman and Powell 1978). Differences in landform, soils, and vegetation produce 6 ecological subsections in the Bluegrass, with four mostly in Kentucky and two mostly within Indiana

(McNab et al. 1994). The Silurian age dolomite of the Western Bluegrass Subsection in Kentucky is a major glade producer with generally poor glade development throughout the rest of the Bluegrass Section. This unique dolomite glade complex supports an endemic plant species found nowhere else in the world (KSNPC 2012).

Glade Associations

Kentucky State Nature Preserves Commission (KSNPC) in 2009 updated their *Kentucky Natural Communities* classification and delineated 6 types of Kentucky glades based on parent material and topographical position. Over the past 20 years, the *Kentucky Natural Communities* classification and subsequent community discussions (lead by State ecologists) to NatureServe, have become the basis for describing the NatureServe glade associations.

KSNPC (2009) described 6 glade natural communities based on rock type and topographical position with only 2 of these found in the Bluegrass Section. This is shown below with the equivalent NatureServe Association:

KSNPC (2009)		**NatureServe**
Dolomite glade	=	Outer Bluegrass Dolomite Glade
Limestone slope glade	=	Central Limestone Glade
	&	Kentucky Glade Seep
	&	Eastern Knobs Ledge/Cliff Glade Woodland (in part)

Outer Bluegrass Subsection (223Fa)
Kentucky: 1,099,526 ha

This subsection is completely within Kentucky and includes Ordovician age bedrock, especially Eden Shale, but other shales and limestones are also important throughout the area. This subsection largely overlaps much of 2 subsections within other physiographic studies: 1) the Eden Shale Belt (Quarterman and Powell 1978) and the Hills of the Bluegrass (Woods et al. 2002); and; 2) a significant portion of what both sources also term “the Outer Bluegrass” or “Outer Blue Grass” subsection. Note that the names are nearly identical but McNab et al. (1997) covers quite a different area. This is important to mention because, for instance, the Outer Bluegrass Subsection of Quarterman and Powell (1978) includes the Silurian age dolomite glades which are completely within another subsection of McNab’s et al. (1997) delineation, the Western Bluegrass Subsection). Today, much of the natural vegetation has been converted to

pastures or exists as secondary cedar-hardwood forests. Large forest blocks do occur in the east and north part of this subsection (KDGI 2004).

Glade types: Glade development is poor, with no high-quality occurrences known or referenced in this subsection. Glade-like, rocky areas do occur but typically are small and poorly-developed with heavy to moderate past disturbances; the highest concentrations fall along the southern margin of the subsection. A few are gravelly, rocky areas embedded within limestone prairies (e.g., Bouteloua Barrens State Nature Preserve) while others are thinly treed, shallow soil areas of larger, dry woodlands (e.g., Blue Licks State Park Nature Preserve) (Skinner et al. 2002, Mandt et al. 2006). As is typical of moderately eroded, thin-soil prairies and/or woodlands, this habitat is often suitable for glade flora (e.g., side-oats grama *(Bouteloua curtipendula),* Crawe's sedge (*Carex crawei*), prickly pear (*Opuntia),* Eggleston's violet (*Viola egglestonii*). Without management, subsequent cedar invasion, heavy grazing and/or invasive exotic colonization may put many of these populations at risk.

The existence of such ruderal and micro-glade communities becomes more important if ecologists agree that some form of high-quality limestone glade occurred in the Outer Bluegrass Subsection before Euro-American settlement, inferring that natural glades existed in this area but have been severely altered or destroyed, or that the marginal habitat that exists today may have been more abundant before Euro-American settlement and may have supported more sustainable populations of glade flora. Further discussion on glade origins can be found in Lawless et al. (2006). An additional survey for extant glades in this subsection and/or an assessment of the existing quality of outcrops may help to resolve these questions.

Total area mapped: The subsection contains no high-quality mapped glades.

Glade area under protection:

USFS: None State: None TNC: None Other NGOs: None

Note: Populations of glade-associated plants are protected at Bouteloua Barrens State Nature Preserve and Blue Licks State Park Nature Preserve, but no well-developed natural glades have been mapped at these sites.

Plant and animal species of conservation concern: Crawe's sedge *(Carex crawei)* and Eggleston's violet *(Viola egglestonii)* populations occur more frequently outside of this subsection due to better development of glade communities. Protecting and increasing the viability of populations found in these other Bluegrass Subsections and other sections outside the Bluegrass should be the first priority. Hairy false gromwell (*Onosmodium molle ssp. hispidissimum)* (S1) is one of the rarest glade associated plants in this subsection and within the adjacent Inner Bluegrass. Two populations are found on nature preserves south of the Inner Bluegrass, one is state-owned. The other is county-owned (KSNPC 2012).

A list of rare glade plants in this subsection (extant or historic) (KSNPC 2012) follows:

Glade Obligate or Optimal: Side-oats grama (*Bouteloua curtipendula*), Crawe's sedge *(Carex crawei*), rigid sedge (*Carex tetanica*), slender blazing star (*Liatris cylindracea*), yellow false mallow (*Malvastrum hispidum*), stemless evening primrose (*Oenothera triloba*), Great Plains ladies'- tresses (*Spiranthes magnicamporum*), Eggleston's violet (*Viola egglestonii).*

Glade Suitable or Marginal: Western hairy rockcress (*Arabis hirsuta),* yellow gentian *(Gentiana alba*) (RFSS), hairy false gromwell (*Onosmodium molle* ssp. *Hispidissimum*), Western false gromwell (*Onosmodium molle* ssp. *Occidentale*), Eastern eulopus (*Perideridia americana*).

Threats to glades in the subsection: Without proper management, subsequent cedar invasion, heavy grazing and/or invasive exotic colonization will further degrade glade-like habitats and may put many of the rare glade species at risk.

Inner Bluegrass Subsection (223Fb)
Kentucky: 381,449 ha

This subsection represents the central part of the Bluegrass section (completely within Kentucky) and includes the presence of Ordovician age limestones, Kentucky's oldest exposed rocks. It is characterized in part by karst topography. The Kentucky River crosses the southern and western portions of this subsection and has carved a deeply dissected gorge system just south of the town of Nicholasville (the heart of the Kentucky River Palisades) (Quarterman and Powell 1978) . Today, much of the natural vegetation has been converted to horse pastures or developed areas of the Lexington metropolis. A significant forest corridor does remain along the Kentucky River Palisades (KDGI 2004).

Glade types: Glade development is very poor with no high quality occurrences known or referenced in this subsection (KSNPC 2012). Glade-like, rocky areas do occur but typically are small and poorly-developed with heavy to moderate past disturbances.

Total area mapped: The subsection contains no high-quality mapped glades.

Glade area under protection:

USFS: None State: None TNC: None Other NGOs: None

Plant and animal species of conservation concern: Including several historic records and only a few extant ones, yellow false mallow *(Malvastrum hispidum)* (S2) populations have been documented more often around the southern parts of the Inner Bluegrass Subsection than anywhere else in Kentucky (KSNPC 2012). Populations are found on weedy limestone outcrops along rolling uplands above the Kentucky River Palisades but also occur in glades much further west (KSNPC 2012).

The following is a list of rare glade plants in this subsection (extant or historic) (KSNPC 2012):

Glade Obligate or Optimal: Yellow false mallow (*Malvastrum hispidum*), stemless evening primrose (*Oenothera triloba*), Eggleston's violet (*Viola egglestonii*).

Glade Suitable or Marginal: Plains muhlenbergia (*Muhlenbergia cuspidata*), hairy false gromowell (*Onosmodium molle ssp. Hispidissimum*), Eastern eulopus (*Perideridia americana*), glade cleft phlox (*Phlox bifida ssp. Stellaria*), Buffalo clover (*Trifolium reflexum*).

Threats to glades in the subsection: Without proper management, subsequent cedar invasion, heavy grazing, and/or invasive exotic colonization will further degrade glade-like habitats and may put many of the rare glade flora at risk.

Western Bluegrass Subsection (223Fc)
Kentucky: 404,696 ha
Indiana: 40,316 ha

This subsection occupies the western part of the Bluegrass section (the majority within Kentucky) and includes the presence of Silurian dolomites and limestones, Ordovician age dolomite and Devonian shales (KGS 2004). Today, much of the natural vegetation has been converted to pastures, croplands or developed areas of the Louisville metropolis. Forested areas of moderate size do remain but mostly are within a band of hills south of Louisville (KDGI 2004).

Glade types: This subsection is the primary range for Kentucky's state-endangered (S1) dolomite glades, with development occurring along the boundary of the Western Bluegrass and the Western Knobs Subsections. The dolomite glades occur in a scattered and fragmented prairie-barrens matrix, which was probably a prominent and distinctive grassland system at the time of Euro-American settlement (based on the current distribution of glade-prairie remnants) (KSNPC 2012, KSNPC 2011). Glade rarity, uniqueness, limited distribution, and the critical habitat provided for endemic species makes this complex state and nationally significant (KSNPC 2012, NatureServe 2011). Conservation of a few sites has been accomplished but further conservation planning efforts should be developed to maintain this system into the future. Community descriptions are provided in the *Kentucky Natural Communities* (KSNPC 2009) as well as a community description in Baskin and Baskin (1975) and include dominant, characteristic, and restricted species.

Total area mapped: The subsection contains 5 mapped dolomite glades totaling 31.8 ha. Only a portion of the existing dolomite glades in this subsection have been mapped. Further surveys are needed.

(Note: The precise boundary between this physiographic subsection and the Western Knobs Subsection is in dispute because some mapped dolomite glades lie within the Western Knobs Subsection. Dolomite glades occur over Silurian age rocks only in the Bluegrass Section and thus boundary delineation is currently thought to be too generalized. Thus, all dolomite glades are discussed and included (area, etc.) in the Western Bluegrass Subsection.)

Glade area under protection:

Federal: None State: KSNPC: 1.6 ha (CE) TNC: <.40 ha
City: McNeely Park Other NGOs: Future Fund and 21st Century Parks

Note: Although the glades are very small outcrops at Pine Creek Barrens Nature Preserve (TNC property), the 61-ha preserve protects one of the highest quality barren-glade matrices in Kentucky.

Plant and animal species of conservation concern: Endemic to Kentucky, Kentucky gladecress *(Leavenworthia exigua* var. *laciniata)* is known only from Bullitt and Jefferson Counties within dolomite glades of the Western Bluegrass Subsection. Over 80 populations have been identified but of these, greater than 90% are fair to poor quality, have not been found in follow-up surveys, or have since been determined extirpated (KSNPC 2012). Only 5 sites are known that protect populations of this plant, with several in degraded habitats. More protected populations are needed to better insure the species viability.

The following is a list of rare glade plants in this subsection (extant or historic) (KSNPC 2012):

Glade Obligate or Optimal: Kentucky gladecress *(Leavenworthia exigua* var. *laciniata*), Great Plains ladies'-tresses (*Spiranthes magnicamporum*), Eggleston's violet (*Viola egglestonii*)

Glade Suitable or Marginal: Hairy false gromwell (*Onosmodium molle* ssp. *Hispidissimum*), glade beardtongue (*Perideridia americana*).

Threats to glades in the subsection: Most glades are declining as a result of change from agricultural farms to residential development, with remnant natural areas being eliminated as the landscape changes. In some situations, glades are declining due to severe degradation by persistent use as pastures (e.g., heavy trampling which leads to soil disturbance and eventual erosion) (KSNPC 2011). ATVs, logging, and quarry mining are also attributed to declines.

The Indiana portion of this subsection contains one documented limestone glade community occuring northwest of the Ohio River in Clark County near Charlestown, Indiana. The site comprises 2 small limestone glades of about 1 ha. The site occurs within the Fourteen Mile Nature Preserve Addition in Charlestown State Park (IDNR 2012).

Indiana area under protection:

Federal: none State: 1 ha TNC: none

Indiana plant and animal species of conservation concern: Several state endangered and threatened species occur in glades in the subsection. Indiana state critically imperiled (S1) plant species inhabiting limestone glades are glade spikerush (*Eleocharis bifida*), Michaux leavenworthia (Leavenworthia uniflora), and Great Plains ladies-tresses (*Spiranthes magnicamporum*) (IDNR 2012). Additionally, several other state endangered plants occur in nearby non-glade habitat at these sites.

Indiana threatened (S2) Glade Obligate: Slender heliotrope (*Heliotropium tenellum*).

Other Glade Obligate or Optimal: Grooved yellow flax (*Linum sulcatum*), and limestone adder's tongue (*Ophioglossum engelmannii*).

Northern Bluegrass Subsection (223Fd)
Kentucky: 236,215 ha
Indiana: 165,442 ha
Ohio: 171,449 ha

This subsection includes parts of Kentucky, Indiana and Ohio and roughly lies along a 249-km section of the Ohio River, from just east of Maysville, Kentucky to near Madison, Indiana. It includes a few large stream drainages including Whitewater River in Indiana and Brush Creek of Adams County, Ohio. The subsection includes the presence of Upper Ordovician age limestones and shales, as well as more recently laid glacial deposits (KGS 2004). Today, much of the natural vegetation has been converted to pastures, developed areas of the Cincinnati metropolis, or exist as secondary cedar-hardwood forests. A moderate-sized forested area does remain in western Boone County near the Ohio River (KDGI 2004).

Glade types: In Kentucky, glade development is very poor with no high-quality occurrences known or referenced in this subsection.

Total area mapped: The subsection contains no high-quality mapped glades in Kentucky.

Glade area under protection:

USFS: None State: None TNC: None Other NGOs: None

Plant and animal species of conservation concern: For Kentucky, all occurrences of rare glade species in this subsection are historical accounts (e.g., side-oats grama (*Bouteloua curtipendula*), stemless evening primrose (*Oenothera triloba*), etc.) (KSNPC 2012).

Threats to glades in the subsection: KY: Not enough development to threaten

Research and monitoring efforts: KY: Not enough development to study

The Indiana portion of this subsection contains only one documented glade community of limestone that occurs in the northwest corner of Franklin County. The Franklin County site is a small limestone glade of about 1.5 ha (IDNR 2012).

Indiana area under protection:

Federal: none State: none TNC: none

Indiana plant and animal species of conservation concern: No state endangered and threatened plant species occur in glades and barrens in the subsection (IDNR 2012).

Glade Obligate or Optimal: Yellow gentian (*Gentian alba*), Indiana state rare (S2) species.

Muscatatuck Flats and Valleys Subsection (223Fe)
Indiana: 424,881 ha

The Indiana portion of this subsection contains three documented limestone glade communities, which all occur in the Indiana State Falling Timbers Nature Preserve. The sites are in Ripley Franklin County (IDNR 2012).

Indiana area under protection:

Federal: none State: 2.3 ha TNC: none

Indiana plant and animal species of conservation concern: No state endangered and threatened plant species, which typically inhabit glades and barrens, exist in the subsection. Schreber's aster (*Aster schreberi*), is a state endangered (S1) plant that occurs in the nearby forest next to the limestone glades in the Falling Timbers Nature Preserve (IDNR 2012).

Glade Obligate or Optimal: Yellow gentian (*Gentian alba*), an Indiana state rare (S2) species.

Scottsburg Lowland Subsection (223Ff)
Indiana: 255,059 ha
Kentucky: 3,336 ha

The Indiana portions of this subsection contain scattered siltstone glades with 4 documented sites near the Ohio River in Floyd County and another area further north in Jackson County, in a complex of 18 small sites in the Knobstone area of the Jackson-Washington State Forest. The siltstone glades range in size from about .24 - 2.24 ha (IDNR 2012). All of these siltstone glades comprise about 22.6 ha. Three of the Jackson County sites (3.1 ha) occur within the Indiana State Knobstone Glade Nature Preserve, and the remaining glades are within the Jackson-Washington State Forest (IDNR 2012). Homoya (1994) describes these siltstone glades as primarily shaly siltstone, while other areas consist of sandstone and shale fragments.

Indiana area under protection:

Federal: none State: 3.1 ha TNC: none

Indiana plant and animal species of conservation concern: No state endangered and threatened plant species, which typically inhabit glades, occur in the subsection. Harvey's buttercup (*Ranunculus harveyi*), is a state endangered (S1) plant that occurs in the nearby rocky, wooded hillsides near the siltstone glades in Floyd County. The state endangered (SE) southeastern

crowned snake (*Tantilla coronata*) also has a known occurrence in this area of the subsection (IDNR 2012).

Glade Obligate or Optimal: There are no known state rare species documented near these glade communities (IDNR 2012).

Central Till Plains Oak Hickory Section (223G)
(4,360,484 ha total in Illinois and Indiana):

Although the subsections in this section occur within the Central Hardwoods Assessment Area, no glades are known to occur within them.

Conservation Recommendations:

While it is not the purview of this assessment to make explicit glade management recommendations, we feel it is important to suggest a strategy for moving from the assessment to a Central Hardwoods and Ouachita glade conservation plan, as follows:

1. Each state's respective conservation agencies and organizations should review the glade assessment to determine where important information gaps still exist for glade habitat and species of conservation concern. Such information should be relevant in setting future management and/or conservation goals and objectives.

2. Determine whether existing information on the location of distinct glade associations is sufficient or of high enough resolution to make conservation decisions. If not, then consider a comprehensive glade mapping inventory. Some states know the locations of all or nearly all of their respective glades as the number of glades is relatively small. However other states contain ecological units that likely contain previously unknown glade locations (especially Missouri, Arkansas and Oklahoma).

   Paul Nelson, lead author of this document, has developed a GIS-based technique for mapping glades and glade complexes using remotely sensed data that should be applicable across the assessment region; Paul began the mapping process in 2012. The Missouri Department of Conservation provided funds to map additional glades and the mapping will be completed for at least 300 quadrangles by May 2013. The Central Hardwoods Joint Venture will provide additional funds to Paul to complete the mapping of all the glades within Missouri in 2013.

   Arkansas and Oklahoma should conduct a statewide comprehensive glade mapping inventory similar to that being carried out in Missouri. Such an inventory will provide information on the extent, type, distribution patterns and relationships to the occurrences of plant and animal species of conservation concern. Both states likely contain extensive numbers of various glade types across different ecological subsections to the extent that significant information gaps currently exist from which to make wise conservation decisions.

3. Once a glade inventory is completed, respective state conservation planners should determine whether additional natural features inventories are needed to gather additional element occurrences for species of conservation concern. Such inventories will also help determine the extent of previously unknown but high quality glades. Conservation organizations or scientific researchers can also use the spatial extent of glades to analyze

glade numbers and acreages by geological rock type, ecological section or land type association, ownership and many other spatial layers.

4 Each state should identify all glades under active management for ecological values or target species. The most useful information would come from mapping glade polygons for the respective ecoregion, then overlaying the map with other spatial layers such as public managed lands or locations for sensitive species.

5. With completed inventories, new element occurrence records and a spatial analysis, conservation planners should identify unrepresented glade (and associated woodland) natural communities and associated species of conservation concern. They should then set criteria for developing conservation goals and objectives that will further protect distinctive glade types and viable populations of associated species of conservation concern.

6. The Missouri glade inventory has thus far shown that the majority of the present 75,000 glade polygons distributed across the Missouri Ozark Highlands are on private lands. Conservation planners should consider strategies for encouraging private landowners to manage their glades for purposes of protecting plant and animal biodiversity.

7. Glades typically are embedded in dry woodland complexes that are overstocked as a result of decades of fire suppression. While many species of plants of conservation concern are associated with the glades themselves, the animal species associated with glade systems (see appendix X) typically range well into, and are dependent upon, the woodland matrix as well. Glades restoration efforts should employ thinning and prescribed fire throughout the glade/woodland complex to provide adequate suitable habitat for target animal species.

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Appendix 1. Regional Forest Sensitive Species for the Assessment Area.

Regional Forester Sensitive Species associated with glade habitats for the Hoosier, Mark Twain, Ozark-St. Francis, Ouachita and Shawnee National Forests

Species and Common Names			Each state column shows state rank and glade habitat preference. If blank, then species does not occur in that state.									
			Tenn.	Arkansas	Okla.	Kentucky	Indiana	Alabama	Illinois	Missouri	Glade Type #	
Plants												
Agalinis skinneriana	Skinner's False Foxglove	G3G4	S1S2	SH Opt	SH Opt	SH Mar			S2 Suit	Opt		MT
Amorpha ouachitensis	Ouachita Leadplant	G3		S3 Suit	S1 Mar						7825	OSF-Ouachita
Buchnera americana	Bluehearts	G5		Suit	Mar		S1 Mar	Opt	S3 Mar		2398	HO, SH
Callirhoe bushii	Bush's Poppy Mallow	G3	S2 Ob	G3S3 Suit	S1 Suit					S2	2398, 7812	Ozark SF, MT
Carex cherokeensis	Cherokee Sedge	G4G5	Mar	Suit	Mar	S1 Mar?		Mar		S2 Opt	2398, 2251	MT
Carex tetanica	Rigid Sedge	G4G5				S1 Opt				S3 Opt	5131	MT
Delphinium treleasei	Trelease's Larkspur	G3		S3 Ob						Ob	2398	Ozark SF, MT
Draba aprica	Open-ground Whitlow Grass	G3		S2 Opt	S1 Ob					Opt	2243, 2242, 7825	MT, Ozark SF
Echinacea paradoxa	Yellow Coneflower	G2		S2 Opt						Ob	2398	MT
Echinacea simulata	Wavyleaf Purple Coneflower	G4	S2 Ob	Ob		S3S4 Ob	SU Ob			Ob	5131, 4340, 2398,	MT
Eriocaulon koernickianum	Small-headed Pipewort	G2		S2 Opt	S2 Mar							Ouachita
Eupatorium album	White Thoroughwort	G5		Mar			S1 Mar					HO
Festuca paradoxa	Cluster Fescue	G5		Suit	Mar		S1 Opt		S3S4 Mar	Suit		HO
Gentiana alba	Yellow Gentian	G4		S1 Suit	S1 Suit	S1S2 Suit	S2 Ob			Opt	7833? (OK)	HO, SH
Helianthus occidentalis ssp. plantagineus	Shinner's Sunflower	G5		S1 Opt								Ouachita
Juncus filipendulus	Plains Rush	G5	S2S3 Mar		S2 Suit	S2? Ob		Opt		S? Ob	2398	MT
Liatris scariosa var nieuwlandii	Blazing Star	G5		S2? Suit						S2 Opt		MT
Matelea baldwyniana	Baldwin's Milkvine	G3		Opt	Mar					Opt	2398	MT
Oenothera triloba	Stemless Evening Primrose	G4		Opt	Suit	S1S2 Ob	SX Ob			S2 Ob	5131, 7772, 2398	MT
Ophioglossum engelmannii	Limeston Adder's-tongue	G5		Ob	Mar		S2 Opt	Opt	S2 Ob	Ob	2251, 2398	HO
Phylanthus polygonoides	Knotweed Leaf-flower	G5		S1 Ob	S1 Suit					S1 Ob		MT
Polygala incarnata	Pink Milkwort	G5		S2 Suit	Mar		S1 Mar		S1 Opt	Suit	2243	HO
Polytaenia nuttallii	Prairie Parsley	G5	S1 Suit	Suit	Mar		S1 Opt		Suit	Opt	2398	HO
Scutellaria bushii	Bush's Skullcap	G3		S2 Ob						Ob	2398	MT
Silene regia	Royal Catchfly	G3	SH Suit	S2 Opt	S1 Mar	S1 Mar	S2 Mar		S1 Mar	Suitable	2398	Ouachita, MT, OSF
Solidago gattingeri	Gattinger's Goldenrod	G3?Q	S1 Ob	S1 Ob						Ob	2398, 5131	MT
Tragia ramosa	Noseburn	G5		Opt	Suit					S2 Opt	2398	MT
Triodanis lamprosperma	Venus' Looking Glass	G5?		Suit	Mar					S2 Opt	2398	MT
Valerianella nuttallii	Nuttall's Cornsalad	G2?		S2 Opt								OSF-Ouachita
Valerianella palmeri	Palmer's Cornsalad	G3		S3 Opt	S2 Suit							OSF-Ouachita
Animals												
Crotalis horridus	Timber Rattlesnake	N4	S2	G4	SE							HO
Ob	Obligate											
Opt	Optimal											
Suit	Suitable											
Mar	Marginal											

Appendix 2: RFSS of Insects on the Hoosier National Forest

Scientific Name	Common Name	Nrank	Srank	Grank	State/Forest Status	Occurs/adj Mapped Barrens	Habitat-Community Glade Type	Comments	Obligate	Optimal	Suitable
TERRESTRIAL INVERTEBRATES											
Amblyscirtes belli	Bell's roadside skipper	N3N4	S1	G3G4	ST; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Atrytonopsis hianna	Dusted skipper	N4N5	S1S2	G4G5	ST; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Calephelis muticum	Swamp metalmark	N3N4	S2	G3	ST; RFSS	Yes	Central limestone glade	Indiana = limestone barrens			X
Catocala dejecta	Dejected underwing	NNR	SNR	G4	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Cicindela unipunctata	One spotted tiger beetle	N4	S4	G3	RFSS	Yes	Central limestone glade	Indiana = limestone barrens			X
Cordulegaster obliqua	Arrowhead spiketail	N4	S2S3	G4	SR; RFSS	Yes	Central limestone glade	Indiana = limestone barrens			X
Cycnia inopinatus	Unexpected tiger moth	NNR	S2S3	G4	SR; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Dasychira dorsipennata	Tussock moth	NNR	S1S3	G4G5	SR; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Digrammia eremiata	Three-lined Angle Moth	NNR	S2S3	G4	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Dorydiella kansana	Kansas preacher leafhopper	NNR	S1	GNR	RFSS	Yes	Central limestone glade	Indiana = limestone barrens			X
Eritettix simplex	Velvet-striped grasshopper	N5	S1	G5	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Erynnis martialis	Mottled duskywing	N3	S2S3	G3	ST; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Eucosma bipunctella	A moth	NNR	S1S2	GNR	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Eutettix modestus	A leafhopper				RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Fitchiella robertsonii	Robertson's flightless planthopper	NNR	S1	GNR	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Flexamia reflexus	Indian grass flexamia	NNR	S2S3	GNR	ST;RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Haimbachia floridalis	A sedge moth				RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Hesperia leonardus	Leonard's skipper	N4	S2	G4	SR; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Hesperia metea	Cobweb skipper	N4N5	S2S3	G4	ST;RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Leucania extincta	A moth	NNR		G4	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Melanoplus morsei	A pur-throat grasshopper	N4?		G4?	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Papaipema beeriana	Blazing star stem borer	N2N3	S1S3	G2G3	ST;RFSS	Yes	Central limestone glade	Indiana = limestone barrens			X
Papaipema marginidens	Brick-red borer moth	N4	S1S3	G4	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Papaipema polymniae	Polymnia borer moth	N4	S1S2	G4	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Polyamia brevipennis	Short-winged polyamia	NNR		GNR	RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Polyamia herbida	Prairie bunchgrass leafhopper	NNR	S1S3	GNR	ST;RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Prairiana kansana	A leafhopper	NNR	S1S2	GNR	SE; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Pyrausta laticlavia	Southern purple mint moth	NNR	S1S2	GNR	SR; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Schinia jaguarina	Jaguar flower moth	NNR	S1	G4	SE; RFSS	Yes	Central limestone glade	Indiana = limestone barrens		X	
Ob	Obligate										
Opt	Optimal										
Suit	Suitable										
Mar	Marginal										

Appendix 3: Scientific and Common Names of Plants Referenced in the Assessment

Plant Species Scientific Name	Common name (source Nature Serve)
Abutilon fruticosum	Texas Indian Mallow
Agalinis auriculata	Earleaf False Foxglove
Agalinis skinneriana	Skinner's False Foxglove
Allium cernuum	Nodding Onion
Allium stellatum	Glade Onion
Ammoselinum popei	Pope's Sand-parsley
Amorpha canescens	Leadplant
Amorpha ouachitensis	Ouachita Leadplant
Amsonia hubrichtii	Ouachita bluestar
Andropogon gerardii	Big Bluestem
Anemone caroliniana	Carolina Anemone
Arabis hirsuta	Western Hairy Rockcress
Arabis hirsuta var. adpressipilis	Hairy Rockcress
Archidium alternifolium	a moss
Arenaria patula	Sandwort
Argyrochosma dealbata	Powdery Cloak Fern
Aristida purpurea	Purple Three-awn
Arnoglossum plantagineum	Groove-stem Indian-plantain
Artemisia ludoviciana ssp. mexicana	White Sagebrush
Asclepias meadii	Meads Milkweed
Asclepias purpurascens	Purple Milkweed
Asclepias stenophylla	Slimleaf Milkweed
Asclepias viridis	Green Milkweed
Astragalus bibullatus	Pyne's Ground Plum
Astragalus canadensis	Canada Milk Vetch
Astragalus tennesseensis	Tennessee Milk Vetch
Astranthium ciliatum	Western Daisy
Baptisia australis var minor	Blue Wild Indigo
Baptisia bracteata var. leucophaea	Cream Wild Indigo
Bouteloua curtipendula	Side-oats Grama
Bromus hordeaceus	Soft chess
Bromus japonicus	Japanese chess
Bromus racemosus	Hairy chess
Bromus sterilis	Brome grass
Bromus tectorum	Downy chess
Buchnera americana	Bluehearts
Bouteloua curtipendula	Side-oats Grama
Bumelia lanuginosa	chitin wood
Calamagrostis porteri ssp. Porteri	Porter's reedgrass
Calamintha arkansana	low calamint
Callirhoe bushii	Bush's Poppy Mallow
Camassia angusta	Wild Hyacinth
Camassia scilloides	Wild Hyacinth
Carex bushii	Bush's Sedge
Carex cherokeensis	Cherokee Sedge
Carex crawei	Crawe's Sedge
Carex juniperorum	Juniper Sedge
Carex latebracteata	Waterfall's Sedge
Carex nigromarginata	Black-edge Sedge
Carex planostachys	Cedar Sedge
Carex tetanica	Rigid Sedge
Castilleja coccinea	Scarlet Indian Paintbrush
Castilleja purpurea	Purple Paint Brush
Centaurea maculosa	spotted knapweed
Celtis tenuifolia	Dwarf Hackberry
Cercis canadensis	Redbud
Chaetopappa asteroides	Common Leastdaisy
Chamaecrista fasciculata	Partridge Pea
Chamaesyce missurica	Prairie Broomspurge
Cheilanthes tomentosa	Wooly Lip Fern
Cissus trifoliata	Marine Vine
Clematis fremontii var. riehlii	Fremont's Leather Flower
Cooperia drummondii	Rainlily
Coreopsis grandiflora var. saxicola	Large-flowered Tickseed
Coreopsis lanceolata	Tickseed Coreopsis
Cornus drummondii	Drummond's dogwood
Corydalis crystallina	Mealy Corydalis
Corydalis micrantha ssp. Australis	Southern Corydalis
Crataegus triflora	Three-flowered Hawthorn
Croton monanthogynus	Prairie-tea
Crotonopsis elliptica	Rushfoil
Cypripedium candidum	Small White Lady's-slipper
Cyperus haspan	Sheathed Flatsedge
Dalea candida	White Prairie-clover
Dalea foliosa	Leafy Prairie-clover
Dalea gattingeri	Gattinger Prairie-clover
Dalea purpurea	Purple Prairie-clover
Delphinium alabamicum	Alabama larkspur
Delphinium carolinianum	Carolina Larkspur
Delphinium carolinianum ssp. Calciphilum	Carolina Larkspur
Delphinium treleasei	Trelease's Larkspur
Deschampsia flexuosa	Wavy Hairgrass
Desmodium ciliare	Small-leaf Tick-trefoil
Desmodium illinoense	Illinois Tick-trefoil
Desmodium ochroleucum	Creamflower Tick-trefoil
Diaperia prolifera	Bighead Rabbit Tobacco
Dichanthelium leibergii	Lieberg's Rosette Grass
Diospyros virginiana	Persimmon
Dipsacus fullonum	common teasel
Draba aprica	Open-ground Whitlow Grass
Draba cuneifolia	Wedge-leaved Whitlow-grass
Echinacea paradoxa	Yellow Coneflower
Echinacea sanguinea	Sanguin Coneflower
Echinacea simulata	Wavyleaf Purple Coneflower
Echinacea tennesseensis	Tennessee Coneflower
Eleocharis bifida	Glade Spikerush
Eleocharis compressa	Flat-stemmed Spike-rush
Eleocharis wolfii	Wolf's Spikerush
Elymus churchii	Church's wild rye
Elymus glaucus ssp. Mackenzei	
Erigeron strigosus	Daisy Fleabane
Eriocaulon koernickianum	Small-headed Pipewort
Eriogonum longifolium	Umbrella Plant
Erybia schreberi	Schreber's aster
Erysimum capitatum	Western Wallflower
Eupatorium album	White Thoroughwort
Euphorbia longicruris	Wedge-leaved Spurge
Euphorbia missurica	Prairie Broomspurge
Euphorbia spathulata	Reticullate-seeded spurge
Evax prolifera var. prolifera	Big Head Evax
Evolvulus nuttallianus	Evolvulus
Festuca arundinacea	Tall fescue
Festuca paradoxa	Cluster Fescue
Festuca pratensis	Meadow fescue
Festuca versuta	Texas Fescue
Fimbristylis puberula	Hairy Fimbristylis
Forestiera ligustrina	Upland Privet
Frangula caroliniana	Carolina buckthorn
Fraxinus americana	White Ash
Galium texense	Texas Bedstraw
Gentiana alba	Yellow Gentian
Gentiana puberulenta	Downy Gentian
Gentiana villosa	Striped Gentian
Geocarpon minimum	Geocarpon
Grindelia lanceolata	narrowleaf gumweed
Gymnopogon ambiguus	Broadleaf beardgrass
Helenium autumnale	Sneezeweed
Helianthemum bicknellii	Plains Frostweed
Helianthemum rosmarinifolium	Rosemary Rock-rose
Helianthus eggertii	Eggert's Sunflower
Helianthus hirsutus	Hairy Sunflower
Helianthus occidentalis ssp. occidentalis	Mcdowell's Sunflower
Helianthus occidentalis ssp. plantagineus	Shinner's Sunflower
Helianthus pauciflorus	Stiff Sunflower
Heliotropium tenellum	Slender Heliotrope
Hieracium longipilum	Hairy Hawkweed
Houstonia ouachitana	Ouachita bluet
Hylotelephium telephioides	Allegeny Stonecrop
Hypericum dolabriforme	Straggling St. John's-wort
Hypericum sphaerocarpum	Roundfruit St. John's-wort
Hypoxis hirsuta	Eastern Yellow Star-grass
Isoetes butleri	Butler's Quillwort
Juncus brachyphyllus	shortleaf rush
Juncus filipendulus	Plains Rush
Juniperus ashei	Ashe's juniper
Juniperus virginiana	Eastern red cedar
Koeleria macrantha	Prairie Junegrass
Krigia occidentalis	Western Dwarf-dandelion
Lathyrus pusillus	Singletary Vetchling
Leavenworthia alabamica	Alabama Glade-cress
Leavenworthia aurea	Golden Glade-cress
Leavenworthia crassa	Fleshy-fruit Glade-cress
Leavenworthia exigua var. exigua	Tennessee Glade-cress
Leavenworthia exigua var. laciniata	Kentucky Gladecresse
Leavenworthia exigua var. lutea	Pasture Gladecress
Leavenworthia stylosa	Cedar Glade Cress
Leavenworthia torulosa	Necklace Gladecress
Leavenworthia uniflora	Michaux Leavenworthia
Lechea racemulosa	Illilnois Pinweed
Lechea tenuifolia	Pinweed
Lespedeza cuneata	Sericea Lespedeza
Lespedeza virginica	Virginian bush-clover
Lesquerella angustifolia	Threadleaf Bladderpod
Lesquerella lyrata	Lyrate Bladderpod
Liatris cylindracea	Slender Blazing-star
Liatris mucronata	Cusp Gayfeather
Liatris squarrosa	Scaly Gayfeather
Liatris squarrosa var. compacta	Ouachita Blazing Star
Liatris scariola var nieulandii	Blazing Star
Ligusticum canadense	Nondo Lovage
Ligustrum sinense	Chinese Privot
Linum sulcatum	Grooved Yellow Flax
Lithospermum canescens	orange puccoon
Lithospermum incisum	Narrowleaf Puccoon
Lobelia appendiculata var. gattingeri	Gattinger's Lobelia
Malvastrum hispidum	Yellow False Mallow
Manfreda virginiana	False Aloe
Marshallia caespitosa var. caespitosa	Tufted Marshallia
Marshallia caespitosa var. signata	Tufted Marshallia
Matelea baldwyniana	Baldwin's Milkvine
Matelea obliqua	Angle Pod
Melilotus officinalis	Yellow Sweet Clover
Mentzelia oligosperma	Few-flower Stickleaf
Microstegium vimineum	Japanese stiltgrass
Minuartia drummondii	Drummond's Sandwort
Minuartia michauxii	Michaux's Stitchwort
Mirabilis albida	Pale Umbrella-wort
Miscanthus sinensis	plume grass
Muhlenbergia capillaris	Long-awn Hairgrass
Muhlenbergia cuspidata	Plains Muhlenbergia
Muhlenbergia glabrifloris	Hair Grass
Neckera besseri	a moss
Nemastylis geminiflora	Prairie pleatleaf
Nemastylis nuttallii	Nuttall's Pleatleaf
Nothoscordum bivalve	False Garlic
Oenothera linifolia	Thread-leaf Sundrops
Oenothera macrocarpa	Missouri Primrose
Oenothera perennis	Small Sundrops
Oenothera triloba	Stemless Evening Primrose
Oligoneuron album	Prairie Goldenrod
Onosmodium molle spp. bejariense	Soft-hair False Gromwell
Onosmodium molle ssp. hispidissimum	Hairy False Gromwell
Onosmodium molle ssp. occidentale	Western False Gromwell
Onosmodium molle ssp. subsetosum	Smooth False Gromwell
Ophioglossum engelmannii	Limestone Adder's-tongue
Opuntia humifusa	Eastern Prickly-pear
Opuntia macrorhiza	Low Prickly Pear
Orobanche multiflora	A Broomrape
Oxalis priceae spp. Priceae	Price' s Yellow Wood Sorrel
Panicum capillare	Old Witch Panicgrass
Panicum flexile	Wiry Witchgrass
Paronychia virginica	Yellow Nailwort
Pediomelum esculentum	Large Indian Breadfruit
Pediomelum subacaule	Southern Scurfpea
Penstemon cobaea	Cobaea Beardtongue
Penstemon tenuiflorus	glade beardtongue
Perideridia americana	Eastern Eulopus
Phacelia dubia var. interior	Interior Phacelia
Phylanthus polygonoides	Knotweed Leaf-flower
Physalis pumila	Dwarf Ground-cherry
Phlox bifida	Cleft Phlox
Phlox bifida ssp. stellaria	Glade Cleft Phlox
Physaria filiformis	Missouri Bladderpod
Plantago patagonica	Wooly Plantain
Polygala incarnata	Pink Milkwort
Polygala boykinii	Boykin's Milkwort
Polymnia cossatotensis	Cossatot leafcup
Polytaenia nuttallii	Prairie Parsley
Portulaca pilosa	Purslane
Potentilla arguta	Tall Cinquefoil
Prenanthes aspera	Rough Rattlesnake-root
Prenanthes barbata	Bearded Rattlesnake-root
Psora icterica	a lichen
Psoralidium tenuiflorum	Few-flowered Scurf-pea
Pycnothelia papillaria	a lichen
Quercus acerifolia	Maple-leaf Oak
Quercus muehlenbergii	Chinquapin Oak
Quercus schumardii	Shumard Oak
Quercus stellata	Post Oak
Ranunculus harveyi	Harvey's Buttercup
Rhus aromatica	Aromatic Sumac
Rhus copallina	Winged Sumac
Rudbeckia missouriensis	Missouri Orange Coneflower
Ruellia humilis	Hairy Wild Petunia
Sabatia arkansana	Pelton's Rose-gentian
Salvia azurea var. grandiflora	Blue Sage
Sapindus saponaria var. drummondii	Soapberry
Saxifraga texana	Texas Saxifrage
Schizachyrium scoparium	Little Bluestem
Schoenolirion croceum	Yellow Sunnybells
Scleria muehlenbergii	Muehlenberg's Nutrush
Scleria verticillata	Low Nutrush
Scutellaria bushii	Bush's Skullcap
Scutellaria cardiophylla	Heartleaf Skullcap
Scutellaria parvula	Small Skullcap
Sedum nuttallianum	Nuttall's Sedum
Sedum pulchellum	Widow's Cross
Selaginella arenicola ssp. riddellii	Riddell's Spikemoss
Selenia aurea	Selenia
Sida elliottii	Elliott's Sida
Silene ovata	Ovate Catchfly
Silene regia	Royal Catchfly
Silphium pinnatifidum	Tansy Rosinweed
Solidag buckleyi	Buckley's Goldenrod
Solidago gattingeri	Gattinger's Goldenrod
Solidago nemoralis	Gray Goldenrod
Solidago ouachitensis	Ouachita goldenrod
Sorghastrum nutans	Indian Grass
Spiranthes magnicamporum	Great Plains Ladies'-tresses
Sporobolus clandestinus	Rough Dropseed
Sporobolus heterolepis	Prairie Dropseed
Sporobolus vaginiflorus	Sheathed Dropseed
Stenaria nigricans	Narrowleaf Summer Bluets
Stenosiphon linifolius	Stenosiphon
Streptanthus maculatus ssp. obtusifolius	Clasping Jewelflower
Streptanthus squamiformis	Pine-oak Jewelflower
Symphyotrichum dumosum	Bushy Aster
Symphyotrichum oblongifolium	Aromatic Aster
Symphyotrichum patens	Spreading Aster
Symphyotrichum pratense	Barrens Silky Aster
Symphyotrichum priceae	Wesern Health Aster
Symphyotrichum sericeum	Western Silky Aster
Symphyotrichum undulatum	Wavyleaf Aster
Syntrichia papillosa	a moss
Talinum calcaricum	Limestone Fameflower
Talinum calycinum	Large-flower Fameflower
Talinum parviflorum	Small-flowered Fameflower
Thelesperma filifolium	Thelesperma
Tradescantia longipes	Wild Crocus
Tradescantia ozarkana	Ozark Spiderwort
Tragia ramosa	Noseburn
Trichostema brachiatum	False Pennyroyal
Trichostema setaceum	Narrowleaf Bluecurls
Tridens muticus var. elongatus	Slim Tridens
Trifolium calcaricum	Running Glade Clover
Trifolium carolinianum	Carolina Clover
Trifolium reflexum	Buffalo Clover
Triodanis lamprosperma	Venus' Looking Glass
Utricularia subulata	Zigzag Bladderwort
Vaccinium arboreum	Farkleberry
Vaccinium stamineum	Deerberry
Valerianella nuttallii	Nuttall's cornsalad
Valerianella ozarkana	Ozark Cornsalad
Valerianella palmeri	Palmer's Cornsalad
Verbena simplex	Narrowleaf Vervain
Viola egglestonii	Eggleston's Violet
Zizia aptera	Golden Alexanders

Appendix 4: Glade Animals

While many plant species are closely tied to glade ecosystems (as evidenced by the spreadsheet associated with this assessment) little information is readily available that suggests such a large suite of animal species are entirely dependent upon glades. There are, however, many animals that find suitable or optimal habitat in the fire-adapted savanna and woodland systems in which glades are typically embedded.

Relative abundance of several bird species identified by Partners in Flight (www.partnersinflight.org) as being of continental conservation concern, such as Prairie and Blue-winged Warblers (*Setophaga discolor,* and *Vermivora cyanoptera,* respectively), have been shown to be greater in managed woodland complexes within the Central Hardwoods Bird Conservation Region than in closed canopy forests. Regional species of conservation concern, such as Field Sparrow (*Spizella pusilla*), Eastern Wood Pewee (*Contopus virens*) and Eastern Towhee (*Pipilo erythopthalmus*), show similar patterns (Thompson et al. 2012). Bachman's Sparrow (*Aimophila aestivalis*), another species of continental concern, has been found in glade woodland complexes as well, but much more sporadically than the species above; it reaches much greater abundance in open pine woodlands where it appears to be attracted by the native grass groundcover and sparsely scattered trees (Dunning and Watts 1990, Hamel 1992).

Species of snakes often associated with Ozark glades, such as the Eastern coachwhip *(Masticophis flagellum)* and Western pygmy rattlesnake (*Sistrurus miliarius streckeri*; Johnson 1987), have geographic ranges well beyond the distributions of glade ecosystems. Snakes associated with glades in the Interior Low Plateaus portion of this assessment region, such as the Southeastern crowned snake (*Tantilla coronata*) and corn snake (*Elaphe guttata*), also are widely distributed. Two mammals that have been suggested to us as being closely tied to glades are the Eastern Wood Rat (*Neotoma floridana*) and Texas mouse (*Peromyscus attwateri*), but these species have relatively large geographic ranges that overlap habitat types that don't include extensive glade systems.

The Eastern collared lizard (*Crotaphytus collaris collaris*) is widespread across the southern plains, but is largely restricted to glades in the Ozark region. Research has shown that the species suffers greatly from inbreeding in landscapes where fire suppression across the glade-woodland matrix results in the effective isolation of glade patches, but can persist in stable metapopulations after fire is used to remove the dense woody vegetation between glade patches that serve as barriers to dispersal (Templeton et al. 2011).

Although a number of species of invertebrates, especially insects, find suitable habitat on glades, most will use other habitat types associated with dry woodlands; many of these species also have broad geographic ranges. The Ozark swallowtail (*Papilio joanae*), however, is restricted to

glades and dry woodlands in Ozarks region, with one isolated record from Kentucky. The species isn't rare within its range, but the small range size could make it vulnerable to habitat loss as it does not use highly disturbed or agricultural habitats (the Xerces Society). Larval hostplants are yellow pimpernel (*Taenidia integerrima*), meadowparsnip (*Thaspium* sp.), and golden alexanders (*Zizia aurea*). Adults drink nectar of rose verbena (*Glandularia* sp.), wood betony (*Stachys* sp.), puccoon (*Lithospermum* sp.), and false garlic (*Nothoscordum* sp.). There also is a disjunct population of Tiger beetle (*Cicindela obsoleta vulturina*) associated with glades and woodlands in the Ozarks, that, if found to be a distinct subspecies, could warrant increased conservation attention (http://beetlesinthebush.wordpress.com/2010/10/10/missouris-disjunct-population-of-cicindela-obsoleta-vulturina). A survey of insects on barren and glade systems on the Hoosier National Forest in Indiana also indicates that other disjunct populations of Great Plains species inhabit that area (Kirk Larson, pers. comm.; Appendix 2). The fauna of glade and woodland systems appears to warrant additional inventory and research.

Appendix 5. Glade Plant Species of Conservation Concern

This appendix can be downloaded as an excel file on the following webpage:
http://www.chjv.org/CHJV_Conservation_Projects.html

Appendix 6: Glade Animal List

This appendix can be downloaded as an excel file on the following webpage:
http://www.chjv.org/CHJV_Conservation_Projects.html