

A Vegetation Survey of Cliff Systems in Cumberland Gap National Historical Park

Gary L. Walker, Ph.D., Department of Biology, Appalachian State University
Mike D. Madritch, Ph.D., Department of Biology, Appalachian State University
Justin Harkey, Master's degree candidate, Department of Biology,
Appalachian State University
Laura Boggess, Master's degree candidate, Department of Biology,
Appalachian State University
Eric Purdy, Master's degree candidate, Department of Biology,
Appalachian State University
Tim Whitby, U.W. Madison, Research Technician

Technical support provided by:

Dr. Keith Bowman
Derrick Poindexter
Dr. Coleman S. McCleneghan

Abstract:

A vegetational survey of the cliff systems located in the Cumberland Gap National Historical Park (CUGA) was conducted during the summer of 2011 and 2012. Vascular plants, mosses, and lichens were surveyed on the cliff edge (top), cliff face, and talus using a systematic sampling protocol along 25 individual transects that were grouped into 11 cliff sites. Transect and plot locations with respective biotic and abiotic features were used to amend a previously constructed GIS database of the White Rocks cliff system located within the Park. Plant diversity throughout the Park was high, with 111 vascular plant, 37 bryophyte, and 83 lichen (231 total) species collected and identified. Species-area curves indicate that the biota were sufficiently sampled for diversity, and, predictably, larger cliff systems harbored higher levels of plant and lichen diversity. Plant and lichen communities varied widely across transects and cliff sites and were heavily influenced by whether the cliff edge was forested or consisted of bare, rock outcrops.

Several important findings may be pertinent to natural resource management decisions. The cliff systems of CUGA are exceptionally diverse compared to other parks within the Cumberland Plateau, likely due, in part, to limited or completely absent climbing activities that otherwise disturb cliff faces and denude cliff edges of vegetation. While we found several listed species, they did not occur on the larger cliff systems of CUGA. Consequently, protecting large cliff systems may preserve more species, but not necessarily more rare species. Multivariate analyses indicated that plant and lichen communities varied widely by transects within a cliff system and among different cliff systems. Consequently, each local cliff site should be carefully surveyed before being developed for purposes of recreational climbing. While we were able to estimate the overall species diversity of the cliff systems, a complete listing of all rare species would require more intensive surveys, as rare species were not always located on prominent cliff features. Also, cliff systems with forest canopied cliff edges should be given conservation priority since it appears that such forests are positively impacting the biodiversity of cliff systems in CUGA.

1. Introduction

Cliff systems can be found in nearly every ecosystem throughout the world. While there is no concrete definition that distinguishes a cliff from a steep, sloping bank, three distinct physical components are usually present. Larson et al. (2000) describes a cliff as being a vertical rock outcrop with an edge, face, and talus. The cliff edge is the relatively horizontal area at the top of a cliff, separating the upper ecosystem from the cliff face. The cliff face is the vertical element of the cliff system. The talus area is located at the base of the cliff and is usually composed of eroded rock fragments (Figure 1).

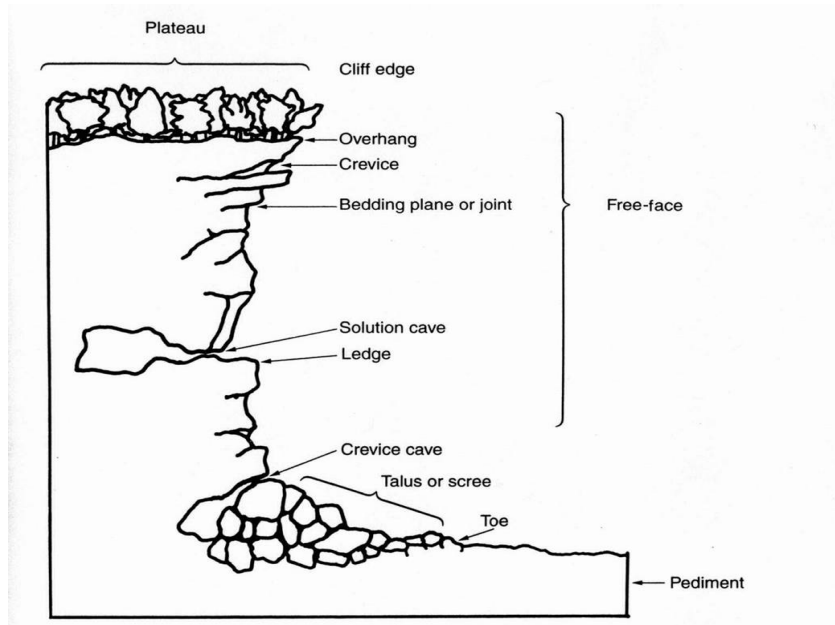


Figure 1 Attributes of a Cliff-Face (Larson et al. 2000)

Cliffs have become a focus for various activities; including photography, advertising, and recreational sports. In response, the establishment of national and state parks have preserved cliffs in their natural state (Larson et al. 2000). This provides researchers with cliff-face study areas of relatively low human impact. Cliff faces along the Niagara Escarpment in Ontario, Canada for example, harbor some of the least disturbed and oldest growth forests in eastern North America (Booth and Larson 1998).

Cliff-Face Ecology

Prior to the 1980's, ecosystem research focused mainly on forests, deserts, oceans, tundra, wetlands, and grasslands (Larson et al. 2000). The lack of studies involving cliff systems was due, in part, to the idea that they were considered either as an ecotone, or geological feature (Ursic et al. 1997). However, today they are considered a distinct and important ecosystem in their own right (Larson et al. 2000). Recent developments in climbing technology are partly responsible for the advancement of cliff-face ecology, making cliff faces accessible for both recreation and biological investigations.

Recent studies have revealed that the vertical orientation of cliff faces results in a challenging environment, characterized by varying temperatures, low nutrient availability and water flux, and almost non-existent soils (Bartlett and Larson 1990). This environment likely impacts species diversity and indirectly provides an important refuge from competitive exclusion for stress-tolerant species (Larson et al. 1989). *Thuja occidentalis* L., with a main range in boreal forests, is a classic example that utilizes cliff faces as a retreat from more competitively dominant species, especially in its southern, disjunct range (Walker 1987, Bartlett and Larson 1990). Cliff communities are known to harbor other disjunct species, such as relict plants of the Pleistocene glacial period, along with many rare and endemic species that may be absent from the surrounding landscape

(Clebsch and Walker 1988). Several archetypal characteristics are typical of plants found on cliff faces. Slow growth and long life spans provide a semi-closed system that likely excludes the immigration and establishment of new species (Booth and Larson 1998).

Climbing Impacts

As rock climbing and rappelling becomes more prevalent, it is important to understand how they will affect cliff-face plant communities. Farris (1998) demonstrated such disturbances to a cliff system and how it led to deterioration of particular aspects of the community. Abrasion of the rope along the face impacted sensitive lichen communities and structures placed within the rock crevices removed scarce soil and vegetation (Farris 1998). It is also common for climbers and hikers to trample sensitive taxa in the talus area when they hike in, and on the cliff edge when they top off. The fruticose and foliose lichens were among the groups of lichens most impacted by climbing (Farris 1998). Some lichen species serve as important pioneer plants that have been found to contribute to the entire cliff community through rock weathering, fine particulate organic matter production, and alterations in water chemistry. If keystone species are disturbed, then the whole cliff-face community may be affected. McMillan and Larson (2002) showed a similar effect of climbing on the vascular plant and bryophyte communities. As climbing increased, there was an overall decrease in percent cover of vegetation observed. Most climbing-related studies reveal that disturbed cliffs don't exhibit complete species turnover in the presence of climbing, but instead only show a subset of the unimpacted community found in similar, undisturbed cliffs (Kuntz and Larson 2006). This decrease in native species sometimes results in a proportional increase in invasive plants in the community (McMillan and Larson 2002). These climbing studies signify the great need for management plans in order to maintain the integrity of cliff-face ecosystems.

Species-Area Relationships

The majority of biological studies today employ models that interpolate data for entire communities based on a subset of data (Krishnamani 2004, Chung and Jang 2011). Cliff faces usually require more time and effort to sample than an equally-sized horizontal landscape. Increased time and effort make it essential for researchers to utilize models to accurately and efficiently describe a cliff face. Arrhenius (1921) developed a well-known quantitative model that explains the correlation between species diversity and the area of their habitat. This relationship presented a practical way of understanding a system in terms of its species richness and diversity based on its size. Under normal circumstances, the relationship shows an increase in species with an increase in area, to a certain extent (McArthur and Wilson 1963, Neigel 2003). The species-area curve is explained by the formula: $S = cA^z$, where 'S' is the number of species, 'A' is the area, 'c' is a constant representing the y-intercept of the log-log plot, and 'z' is a constant representing the slope of the log-log plot. The slope is most important for interpretive purposes and, depending on the habitat, usually falls within a set range of values. Species-area curves for isolated habitats, such as cliffs and islands, have slopes ranging from 0.20 – 0.40, whereas non-isolated habitats have a species-area curve with slopes ranging from 0.12 – 0.19 (MacArthur and Wilson 1967). The asymptote and the slope of the curve indicate how diverse a system is and how quickly the majority of that diversity

is achieved. Slope values also vary based on the scale: local, regional, or continental. Local and continental habitats have a relatively steep slope, whereas regional habitats have a more gradual slope (Connor and McCoy 1979, Rosenzweig 1995).

As climbing becomes more popular, efficiency of sampling is crucial for developing management plans to minimize human impacts on a cliff face. Species-area curves can be useful in developing these climbing management plans by determining the appropriate habitat size for conservation prioritization. A single large habitat is continuous with more resources, whereas several small habitats may offer a greater diversity of niches. With several small habitats, more endemic species that require specialized niches are protected (Losos and Ricklefs 2010). However, the non-continuous nature of the small fragments can compromise extinction-prone species with small population sizes (Neigel 2003, Losos and Ricklefs 2010). Creating web-like corridors between patches can alleviate some of the problems caused by fragmentation of the landscape. In general, simply preserving species-specific habitat seems to be more important than actual patch sizes (Losos and Ricklefs 2010).

The goal of this study was to collect species-area data from several small, spatially fragmented cliffs and larger more continuous cliffs within the Park. There are several questions that will be addressed in this study: 1) Are the sub-sampling techniques presented in this study effective at capturing the representative diversity of cliff-face communities? 2) Can a useful species-area curve be applied to cliff-face ecosystems? (3) What physical and biotic factors drive variation in plant communities on cliff faces?

2. Materials and Methods

Study Site

Cumberland Gap National Historical Park (CUGA) is located at the escarpment of the Cumberland Plateau physiographic region and the Ridge and Valley physiographic region, at the state borders of Tennessee, Kentucky, and Virginia. The cliff faces within the Park are part of the Lee Formation, composed mainly of a sandstone conglomerate (Hinkle 1975, Rice 1984). The area receives an average of 127 cm of rain per year, with a humid climate that is typically five to ten degrees cooler than the surrounding lower elevations (Hinkle 1975). Most of the cliff systems in the Park can be approached from the west via the Ridge Trail or from the south via the Thomas Walker Civic Park and the Ewing Trail, in Ewing, Virginia. The area closest to the cliff edge supports a vegetative community consisting of low shrubs interspersed with hardwood tree species including *Hamamelis virginiana*, *Rhododendron catawbiense* and *Quercus* species. This forest type was first described as the Chestnut Oak association but more recently is designated as Appalachian Oak Forest type (Stephenson 1993). Most recently, the forest community in the immediate vicinity of the White Rocks cliff system in close proximity to the cliff edge has been described as Southern Appalachian Mountain Laurel Bald (White 2006).

Field Collections

The data from CUGA was collected in the summer of 2011 and 2012 by a team of cliff-face researchers from Appalachian State University (ASU) Department of Biology. Transects were chosen to span the east-west expanse of the Park, complementing the previously sample White Rocks cliff system (Figure 1). A photograph and GPS

coordinates were recorded at each transect location where the rappelling anchors were established.

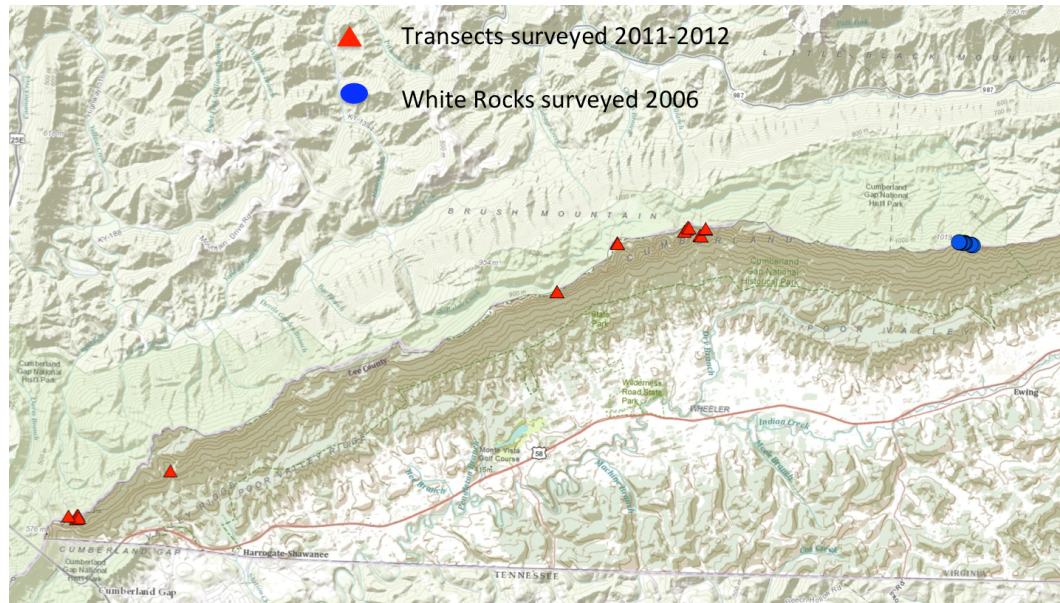


Figure 2. Proximate locations of White Rocks (2006) and current survey transects.

Transects, which extended from the cliff edge to the cliff base and included any areas of bare rock on the cliff edge and talus, were surveyed from top to bottom. Along each transect, 1m^2 plots were surveyed every three meters, beginning one meter away from the cliff edge, and extending one meter beyond the cliff base or as necessary to include continuous areas of bare rock (Fig. 3). Area of the cliff face was then determined by measuring the length and width of the cliff-face.

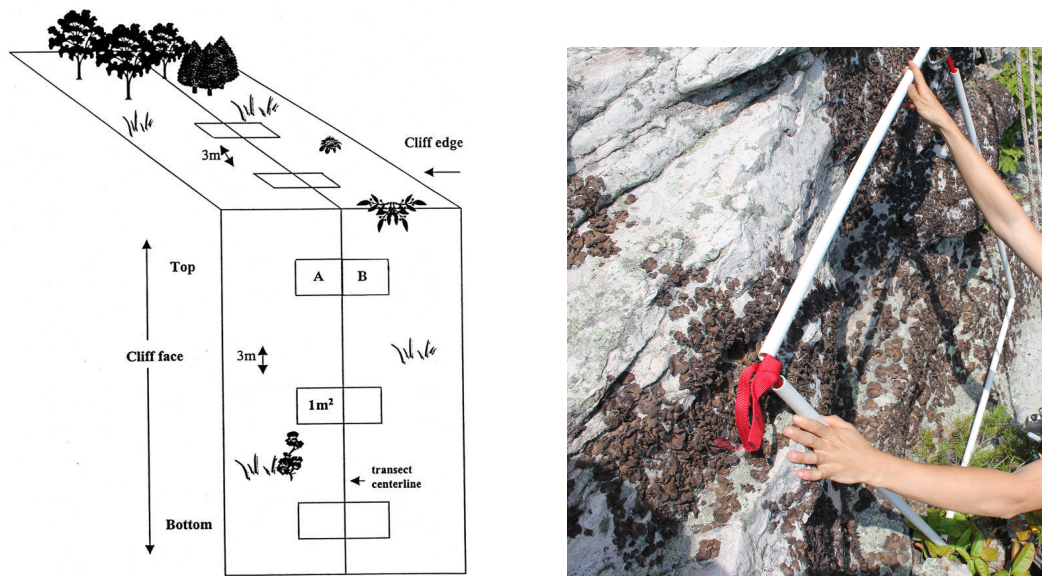


Figure 3. Diagram of the sampling design and 1m^2 quadrates used on either side of the rappel line.

Samples of vascular plants, lichens, and bryophytes were collected from paired 1m² plots (A and B separated left and right by the rappel line) along each transect beginning three meters from the cliff-edge and every three meters thereafter. Paired plots were also sampled on the cliff edge and in the talus area (Figure 3). Aspect, slope, and percent cover of each species were recorded in all plots. Percent cover was visually estimated within each quadrat. Aspect and slope were measured with a compass and inclinometer, respectively.

Vegetation samples were temporarily placed in paper bags labeled with transect and plot numbers. Vascular samples were then transferred to a plant press in the field. Upon return to the Appalachian State University herbarium, the plant presses were placed in a dryer for at least one week. Samples were identified by Derrick Poindexter, ASU herbarium, using the nomenclature of Weakley (Weakley 2006). Bryophyte samples were transported to the Appalachian State University herbarium where they were dried for at least one week. These samples were then sent out for analysis by Dr. Keith Bowman, bryologist, SUNY Syracuse, and identified using the nomenclature of Stotler and Crandall-Stotler (1977). When sampling crustose lichens, it was often necessary to remove a small portion of the rock. This was done with a hammer and chisel in a manner which minimized impact and scarring. Lichens samples were returned to Appalachian State University and identified by Dr. Coleman McCleneghan, a mycological consultant, using the nomenclature of Lichens of North America, (I.M. Brody, 2001).

Statistical analyses

Non-nested species-area curves were constructed using JMP (10, SAS, Cary, NC) and nested species-effort curves were constructed with PC-ORD (v6, MjM Software, Gleneden Beach, Oregon). Estimated species numbers were calculated using the first-order jackknife estimator in PC-ORD (Palmer 1990, Smith and Pontius 2006).

We employed Multiresponse Permutation Procedures (MRPP) to determine if plant communities on cliff edges differed from those on the cliff face (cliff edge effects) and if communities differed by transect (transect effects). In addition, because several transects were used to survey contiguous cliffs, we grouped adjacent transects that covered continuous cliff systems, and employed MRPPs to determine if plant communities differed by cliff system (cliff site effect).

Community data are typically complex and require ordination procedures to distill multivariate data into more tangible dataset. We employed Non-metric Multidimensional Scaling (NMS) to describe variation in plant communities. NMS makes no assumptions regarding sample distribution, and is often best suited for highly skewed, non-normal, and sparse ecological data (McCune and Grace 2002).

GIS Database

Two GIS databases were developed from this survey. First, an ArcGIS database originally developed by Walker for the White Rocks cliff system within the Park (Ballinger 2007) was updated to include all newly-found species. See Ballinger (2007) for database description and metadata. In addition, a simpler, more user-friendly KMZ file was developed for non-GIS savvy personnel. KMZ files are accessible with Google Earth. The KMZ database includes transect location, species list, and listing status by transect.

3. Results

Species Richness

111 vascular plant species were found on the cliff systems in the present study, including *Melampyrum lineare* var. *latifolium*, listed as imperiled in the State of Kentucky, . *Dicchanthelium aciculare*, endangered in the State of Tennessee and a biogeographical disjunction in the State of Virginia, and *Rhododendron carolinianum*, a state record in the State of Virginia. Thirty seven bryophyte species were found on the cliff systems. 83 lichen species were found on the cliff systems, including *Cladonia pocillum* which is a boreal and Rocky Mountain disjunct, also found among other such disjunct lichens on White Rocks. Table 1 compares the number of vascular, bryophyte and lichen species identified in the present survey of 11 cliff systems in CUGA, with those on the White Rocks cliff system (Ballinger 2007) and six cliff systems surveyed at the Obed Wild and Scenic River National Park, (Walker and Parrisher 2005). The diversity of lichen taxa was much higher at in the present CUGA cliff system survey than White rocks, and Obed even when all systems were totaled. The bryophyte diversity at White Rocks and in the present CUGA survey was much lower than that observed at Obed. The level of vascular plant diversity found in the present CUGA survey was much higher than those found in the Obed and White Rocks studies.

Table 1. Comparison of vascular plant, bryophyte and lichen diversity between the present CUGA survey, White Rocks and the Obed Wild and Scenic River Cliff systems.

	Obed River Gorge (six cliff systems)	White Rocks (one cliff system)	CUGA Cliff systems (11 cliff systems)
Total Vascular plant species	58	14	111
Total Bryophyte species	65	9	37
Total Lichen species	47	48	83

Species-area curves

The non-nested species-area curves for all species approached asymptotes (Figure 4), indicating that our sampling regime was sufficient to estimate plant diversity within cliff systems in the Park.

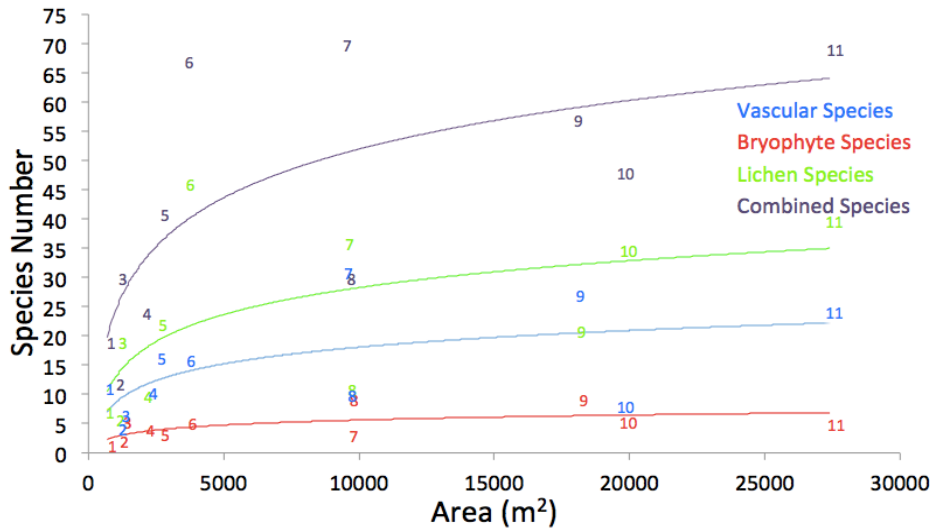


Figure 4. Non-nested species-area curves for cliff sites sampled in CUGA. Each number denotes a distinct cliff site sampled (Table 2), and each trend line corresponds to bryophyte, lichen, vascular, or total species (Combined).

Table 2. Site characteristics for each of the cliff sites sampled in CUGA. Cliff faces are listed by increasing area.

Cliff Site	Location	Area (m ²)	Total Species Richness
1	Ridge Trail 2	683	19
2	Ridge Trail 1	1116	12
3	Upper Chadwell	1195	30
4	Lewis Hollow	2087	24
5	Indian Rocks	2637	41
6	Pinnacle Overlook	3641	67
7	West Chadwell	9564	70
8	Skylight Cave	9639	30
9	Lower Chadwell	18064	57
10	Cumberland Trail	19685	48
11	Teaberry	27400	69

Table 3. Line equations and R^2 values calculated in JMP for non-nested species-area curves for cliff-faces sampled in CUGA.

Class	Line Equation	R^2
Vascular	$\text{Log}(y) = 0.0513 + 0.2932 \times \text{Log}(x)$	0.35
Bryophyte	$\text{Log}(y) = -1.4758 + 0.3385 \times \text{Log}(x)$	0.47
Lichen	$\text{Log}(y) = -0.1855 + 0.3695 \times \text{Log}(x)$	0.44
Combined	$\text{Log}(y) = 0.7437 + 0.3407 \times \text{Log}(x)$	0.57

A nested species-effort curve was created in PC-ORD and displays species accumulation per sampling effort (Figure 5). This analysis was used primarily to

estimate species richness using the first-order jackknife estimator in PC-ORD (Table 3) (Palmer 1990, Smith and Pontius 2006). Our observed values of species richness were much closer to jackknife estimates for vascular and bryophyte species than for lichens. Lichens were the most underestimated taxa, as observed richness was only 57% of estimated diversity. Figure 5 could indicate that further lichen sampling is necessary to fully inventory the Park. However, it is likely that the jackknife estimates overestimated lichen diversity by heavily weighting the lichen-diverse Pinnacle Overlook site (cliff site 6 in the Figure 4). The stable asymptote in Figure 4 supports the conclusion that lichens were sampled thoroughly.

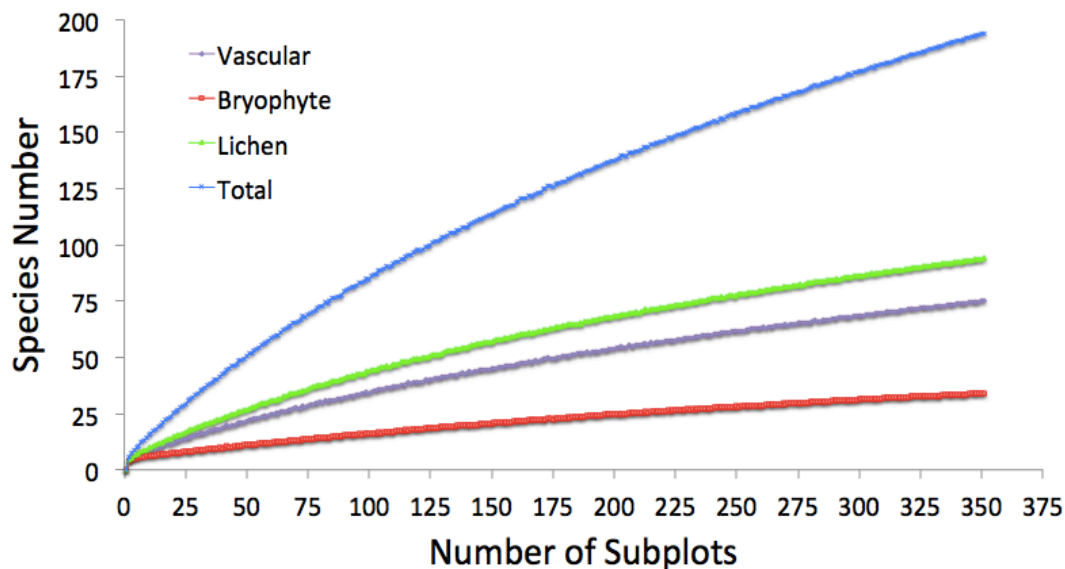


Figure 5. Nested species accumulation curves for cliff faces sampled in CUGA.

Table 4. Expected species numbers using the first-order jackknife estimator in PC-ORD

Taxa	Observed Richness	Estimated Richness
Vascular	111	118
Bryophyte	37	52
Lichen	83	145
Total	231	315

MRPP Analysis

We employed multi-response permutation procedures (MRPP) with Bray–Curtis distances to test for differences among vegetation communities (Antoninka et al. 2009). MRPP *p*-values indicate significance, and the *A* statistic represents the effect size. A small effect size ($A \rightarrow 0$) indicates that heterogeneity within groups equals that expected by chance; a large effect size ($A \rightarrow 1$) indicates that all values within a group are

identical. An *A* value greater than 0.3 is considered high, and ecological data commonly have *A* values around 0.1 (McCune and Grace 2002, Antoninka et al. 2009). The test statistic, *T*, describes the separation between groups, with more negative values indicating more separation (McCune and Grace 2002). MRPP tests were used here to determine if plant communities on cliff edges differed from those on the cliff face (cliff edge effects) and if communities differed by transect (transect effects). In addition, because several transects were used to survey contiguous cliffs, we grouped adjacent transects that covered continuous cliff systems, and employed MRPPs to determine if plant communities differed by cliff site (cliff site effect). MRPP results indicate several important relationships; transect and cliff site influence all species groups. This indicates that all vegetational communities varied by both transect and cliff site. In addition, all vegetational groups, except for bryophytes, varied by cliff face compared to cliff edge. This indicates that cliff-face communities were significantly different than those found on the edge of the cliff system (see Fig 3 above for cliff edge definition).

Table 5 MRPP results calculated in PC-ORD for cliff-faces sampled in CGNHP.

Cliff-Edge effect

	T	A	P
Vascular	-28.229	0.025	*P<0.001
Bryophyte	-0.697	0.0007	0.179
Lichen	-23.913	0.015	*P<0.001
Total	-9.949	0.004	*P<0.001

Transect effect

	T	A	P
Vascular	-7.881	0.041	*P<0.001
Bryophyte	-25.871	0.15	*P<0.001
Lichen	-54.57	0.187	*P<0.001
Total	-61.259	0.161	*P<0.001

Cliff site effect

	T	A	P
Vascular	-5.584	0.019	*P<0.001
Bryophyte	-14.066	0.052	*P<0.001
Lichen	-37.4	0.081	*P<0.001
Total	-40.607	0.068	*P<0.001

NMS Ordination

Non-metric Multidimensional Scaling (NMS) NMS are ideal for non-normal, scarce datasets typical of ecological community data (McCune and Grace 2002). They are largely complimentary to MRPP analyses, and provide a visual representation of community differences. Figure 6 shows the NMS ordination of cliff-face and edge communities, and demonstrates that while cliff-face and edge communities were different from each other, cliff communities were comprised of edge species in addition to cliff-

face specific species. NMS ordinations for cliff transects and cliff sites were overly crowded and not particularly useful, and are therefore omitted for brevity

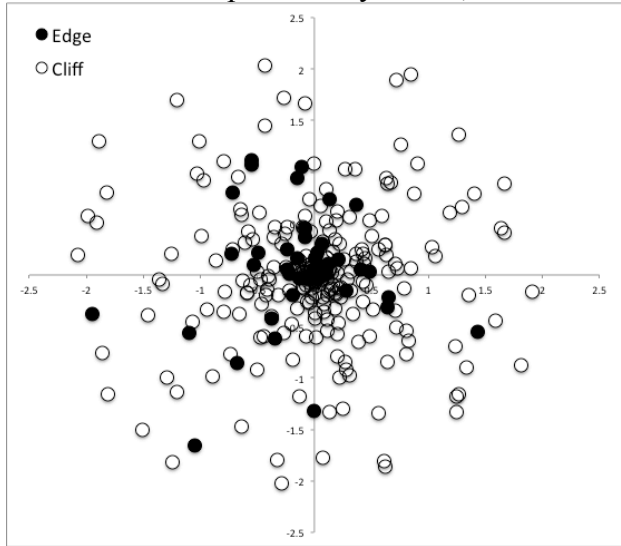


Figure 6. NMS ordination comparing the edge plot with the face plots for the total species sampled on all eleven cliff faces in CUGA.

Our species-area curves indicated that transects with open canopies at the top behaved differently than those with closed canopies (e.g. site 6 Figure 4). However, we lacked sufficient replicates of open canopy transects to make a comparison. Consequently, we combined transect data from the previously sampled White Rocks cliff system and performed ad-hoc tests. Both MRPP and NMS analyses appear to demonstrate that cliffs with open canopies at the top differed significantly from those transects with a closed forest canopy at the top with respect to vegetational community structure (MRPP: $T = -13.1$, $A = 0.09$, $P < 0.001$).

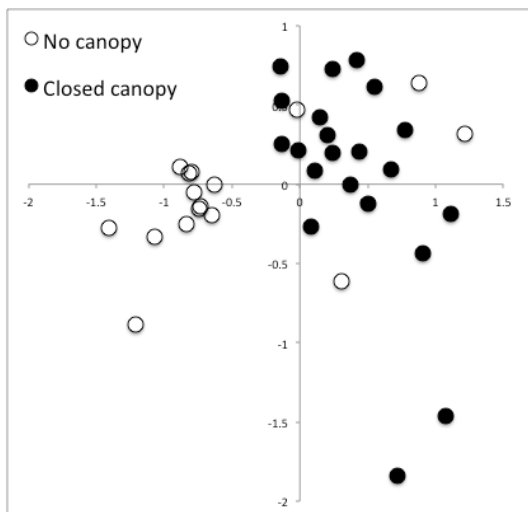
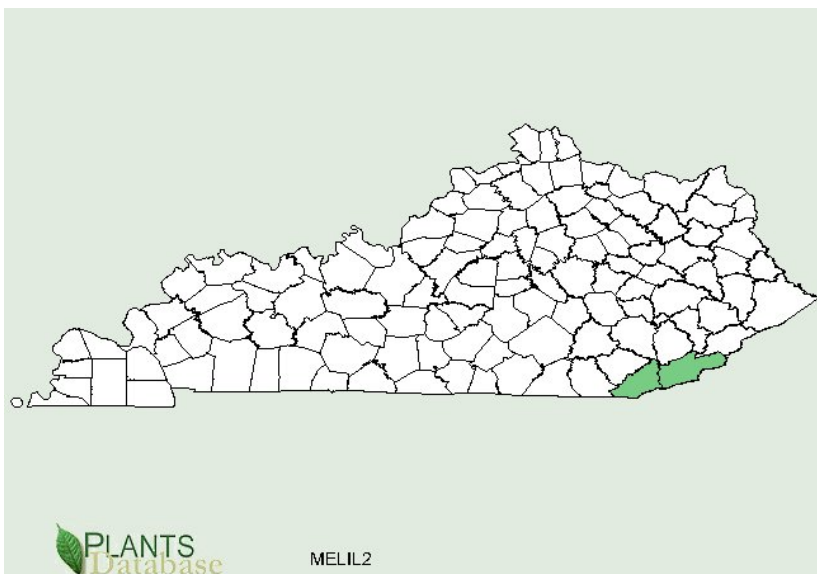


Figure 7. NMS ordination comparing transects with forested, closed canopies at the cliff edge with transects without forest canopies present at the cliff edge. Data are from this project's sampling efforts and those of Ballinger and Walker in the White Rocks cliff system.

Species of special note discovered in this study:

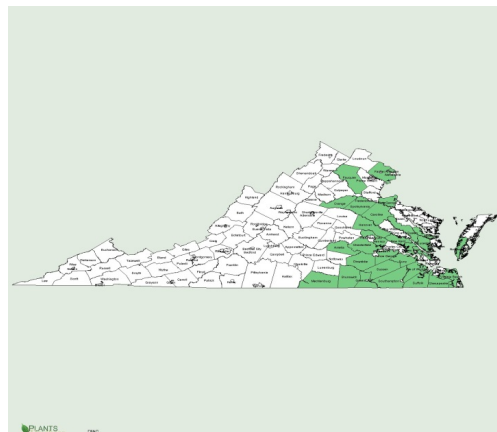
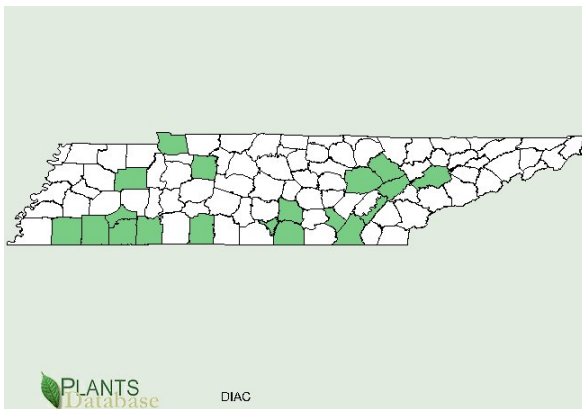


Melampyrum lineare Desr. var. *latifolium* Bart., narrowleaf cowwheat, is a member of the Scrophulariaceae listed as threatened in the State of Kentucky with a global rank of G5T5 (widespread and common) and a state rank of S2 (imperiled). It has an eastern distribution from the mountains of North Georgia northward to Quebec and Ontario in Canada. It is an annual, herbaceous species listed as a facultative wetlands species. It is associated with dry, open, sandstone ridges, often with dry to dry-mesic second growth forests, along road edges and rock outcrops. It flowers from early June to late August.



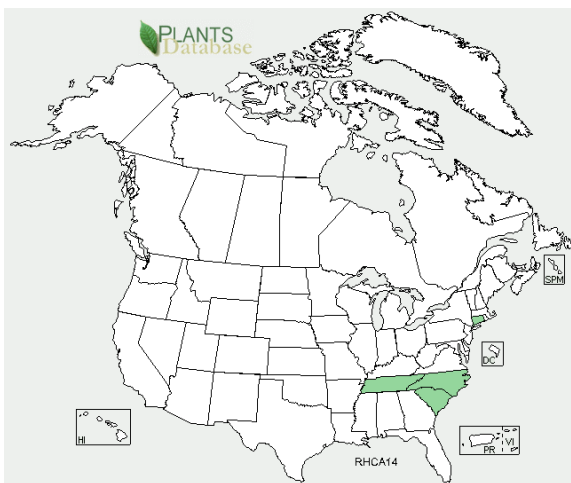


Dicchanthelium aciculare (Desv. Ex Poir) Gould & C.A. Clark, needleleaf rosette grass, is a member of the Poaceae family listed as (E) endangered in the State of Tennessee under the common name of needleleaf witchgrass,. It has a southeastern distribution from coastal Texas northward to New York. This species is a county record for the State of Virginia and represents a biogeographical disjunction, as the species range in that state is largely coastal plain and piedmont. It is also listed as a facultative wetlands species. Its habitat is usually sandy, xeric, open old fields and upland oak woodlands. It has gray-green foliage and green flowers with a rapid growth rate reaching a height of 0.3 m. It blooms during the summer and is somewhat tolerant of shade but intolerant of fire.





Rhododendron carolinianum Rehder, Carolina azalea or Carolina rhododendron, is a perennial, mound-shaped evergreen shrub in the Ericaceae family growing from 1-2 m in height. It has a distribution that ranges from Tennessee, to North and South Carolina and with a northern disjunction in the State of Connecticut with regard to native populations but is in cultivation in many states. This is a state record for Virginia and the location in this study is very close (a few meters) from the Kentucky state line where it would also constitute a state record. It is often found in full to partial shade, rooted in moist-well drained acidic soils, often on cliff faces and rock outcrops. It blooms in spring, bearing white to rose or lilac-rose colored funnel-shaped flowers in terminal clusters. It has dark green leaves that are aromatic when crushed and that have a purplish tinge in winter.



Site descriptions:

Ridge Trail 2 and 1 (#1 and #2)

Ridge Trail 1 and 2 cliff systems were the smallest and least diverse of the cliff systems sampled. Despite their low diversity, they contained *Rhododendron carolinianum*, a state record for Virginia. The cliff sites were adjacent to one another, located only a few meters apart. Likely due to their close proximity, both sites represented similar levels of diversity. These cliff sites were located along a paved trail running through the Park and were among the most heavily trafficked areas that were sampled. This may have influenced Ridge Trail 1, which had almost no vegetation on the cliff edge. There was nearly half the number of vascular plant species present on Ridge Trail 1 compared to Ridge Trail 2, which was heavily vegetated above the cliff face. Both cliff sites faced one another and were moderately to heavily shaded. Bryophyte and lichen diversity were relatively similar on both cliff systems.

Upper Chadwell (#3)

This cliff site was located in the middle of a densely wooded area within the Park. The unusually high bryophyte diversity at this site is likely driven by a seep on one transect and because of shading of the face by trees in the talus. The low diversity of vascular plants observed at this site may have been due to lack of vegetation at the cliff edge, perhaps leading to reduced seed rain. Reduced vascular plant seed rain may have released the lichen species from competition, allowing them to increase in abundance and diversity at this cliff system. Despite the low vascular plant diversity, this site contained specimens of *Melampyrum lineare* Desr. var. *latifolium*.

Lewis Hollow (#4)

This cliff site consisted of two adjacent transects with differing aspects. One of the aspects was mostly shaded and moist, likely resulting in the relatively high bryophyte diversity. Both aspects were somewhat exposed, but not nearly as much as some other faces sampled. Lichen numbers were fairly low, probably due to competition for space from vascular plants.

Indian Rocks (#5)

The Indian Rocks cliff site showed a higher than expected number of vascular plant species. The face was only partially shaded, with a significant amount of vegetation on the cliff edge. Vascular plants may have been able to establish themselves from a source population at the cliff edge and outcompete lichen species via shading.

Pinnacle Overlook (#6)

This location had several unique features compared to others sampled in this study. The entire cliff edge was developed into a visitor's overlook and almost completely devoid of vegetation. However, several specimens of *Dicchanthelium aciculare* were collected here. This area also represented a continuous cliff system with three different aspects. The cliff face was also exposed on all sides, and exposure was likely responsible for the significantly higher lichen species diversity observed for this system. The preference of many lichen species for direct sunlight and their tolerance of windblown sand particles may give lichens a competitive advantage in otherwise extreme

conditions such as those at this site. Without vegetation on the cliff edge and with the exposed conditions at this site, there was a likely reduced possibility of vascular plant seed rain and lower vascular plant and bryophyte competitors for the lichens on this cliff face.

West Chadwell (#7)

West Chadwell and Skylight Cave are two sites with approximately the same area, yet very different levels of species diversity. This lends credence to the idea that area is not the only factor driving diversity among the sites sampled. This particular cliff system was observed to have a high level of direct exposure on the cliff face, perhaps resulting in decreased moisture levels and minimal shading. Nonetheless, vascular plant diversity is higher than what would have been expected as predicted by the species-area curve for this cliff system.

Skylight Cave (#8)

At the Skylight Cave cliff system, very different conditions exist as compared to those at the nearby West Chadwell system. The species-area curve underestimated the actual bryophyte diversity observed at this site. There was almost no direct insolation hitting the cliff face, perhaps providing more mesic environmental conditions at this site. Thick canopy cover may have over-shaded vascular plant undergrowth on the cliff face, that may have resulted in the competitive release of bryophytes.

Lower Chadwell (#9)

Lower Chadwell was surrounded by forest canopy, with minimal exposure and direct insolation of sunlight on the cliff face. Many lichen species require more open environments and only a few taxa, such as *Lepraria* spp. thrive in heavily shaded sites.

Cumberland Trail (#10)

The Cumberland Trail cliff site was one of the cliff systems with the greatest height we sampled. It was fully exposed, with an exceptionally diverse lichen community. Vascular plant diversity was less than expected, with the majority of these taxa occurring on a fairly large cliff ledge a few meters from the cliff edge. Bryophyte diversity is low likely due to the exposed habitat at this site.

Teaberry (#11)

This was the largest areal cliff system sampled in the Park. A large amount of heterogeneity along the cliff likely allowed for relatively high levels of diversity observed among both lichens and vascular plants. This extensive cliff system indicates that in some cases a single large cliff system may represent a reservoir of high species diversity.

GIS database files

ArcGIS and KMZ datafiles are available for download:

KMZ located at http://www.appstate.edu/~madritchmd/Cumberland_Gap_2012.kmz

ArcGIS SHP located at

http://www.appstate.edu/~madritchmd/Cumberland_Gap_2012_GIS.zip

4. Discussion

The cliff-face surveys of this study were initiated because of the results of the White Rocks cliff system survey conducted by Ballinger (2007) where several rare species were found in association with that system, one of which was on the cliff face, and owing to a unique assemblage of boreal and arctic disjunct lichen species that had heretofore been undiscovered in the Southern Appalachians. The present study likewise found several rare and disjunct vascular plant species, including state and county records, and one taxa of the boreal disjunct lichen species found in the White Rocks system survey. Moreover, a greater diversity of vascular plant and lichen taxa were found in the present study compared to other cliff system surveys conducted on the Cumberland Plateau (Table 1).

There may be several reasons for the relatively higher plant diversity observed at CUGA in this study. Since Cumberland Gap National Historical Park has been protected from human disturbance in the form of rock climbing, it may be that the cliff systems of CUGA represent more pristine cliff systems than those surveyed at the Obed Wild and Scenic River National Park, which has been heavily-impacted by climbing. The higher diversity of vascular plants, bryophytes and lichens observed in this study compared to that recorded for White Rocks may be due to the diversity of aspects and closed canopy cliff edges in the present study's sites as well as higher levels of heterogeneity of other physical features observed across the many smaller cliff systems of CUGA. The White Rocks cliff edge has been heavily impacted by hikers and 4wheel ATV traffic in the past, in fact throughout the history of this park. The forest edge is set back several meters at White Rocks and the cliff edge is largely bare rock, devoid of any kind of vegetation. The difference in White Rocks and the other cliff systems at Cumberland Gap is highlighted by the observation that there was no significant difference observed among the 12 transects in the White Rocks study, while in the present study significant differences were observed among transects on all the canopied cliff edge systems while open canopied cliff edges in the present study, such as those at the Pinnacle, did not show such difference among transects (Ballinger 2007). Our hypothesis is that a canopied cliff edge provides a seed rain that may cause variations seen among transects sampled on the cliff faces below such systems while uncanopied cliff edges, such as those seen at the Pinnacle and White Rocks, may rely on more random seed dispersal, such as wind and animal vectors, resulting in a homogenizing effect horizontally across the cliff face in such systems. This is statistically substantiated when canopied and uncanopied cliff edge systems are analyzed using MRRP, where there is a significant clustering of canopied vs uncanopied cliff edge sites, $p < 0.001$ (Figure 7). The management implications of this are clear; cliff sites that have canopied edges result in more diverse and heterogenous cliff faces, while those that have uncanopied edges are less diverse. So if climbing access is a consideration, clearly the canopied cliff edge systems of CUGA should have higher conservation priority. Also, a no topping-off policy, such as that successfully adopted at the Obed, should be a consideration for CUGA climbing management as well (Hill 2009).

The Cumberland Plateau has gained recognition as a center of biodiversity in the Southern Appalachians. It has been a refugia for species with more northerly ranges at their southernmost distributional limits. Likewise it has been a refugia for species with

more southern ranges at their northernmost distributional limits. The cliff systems at CUGA represent a series of cliff habitats largely unimpacted by human disturbances. The levels of diversity of vascular plants and lichens in these cliff systems are unparalleled when compared to other cliff systems surveyed in the Cumberland Plateau physiographic province. For these reasons the cliff systems of CUGA deserve a high conservation priority.

6. Management-focused Summary

We have several key summary points that may be relevant to management policy decisions:

1. The vegetational survey methods employed here sufficiently estimated vascular, bryophyte, and lichen diversity.
2. Large cliff sites harbor more species diversity. However, rare and disjunct species were located on smaller cliff sites. Consequently, protecting large cliff systems may preserve more species, but not necessarily more rare species.
3. Plant communities vary significantly by cliff site and transect. Consequently, each local cliff site should be carefully surveyed before being developed for recreational climbing.
4. Cliff sites that have canopied edges have more diverse and heterogeneous plant communities. Cliff edge vegetation should be protected via appropriate trail routing. In addition, if climbing is allowed, a no topping-off policy should be enforced whenever possible.
5. Cumberland Gap National Historical Park harbors an unusually high level of biodiversity on its cliff faces, likely due to the restriction of recreational climbing and the maintenance of intact forests along cliff edges.

Acknowledgements.

We would like to thank Cumberland Gap National Historical Park Staff, and Jenny Beeler in particular, for outstanding logistical support.

References

- Arrhenius, O. 1921. Species and area. *Journal of Ecology* 9:95-99.
- Ballinger, D.A.L. 2007. Physical variables and community structure of the White Rocks cliff system, Cumberland Gap National Historical Park. M.A. Thesis, Appalachian State University, Boone, North Carolina.
- Barnett, D.T. and Stohlgren, T.J. 2003. A nested-intensity design for surveying plant diversity. *Biodiversity and Conservation* 12:255-278.
- Bartlett, R.M. and D.W. Larson. 1990. The Physiological basis for the contrasting distribution patterns of *Acer saccharum* and *Thuja Occidentalis* at cliff edges. *The Journal of Ecology* 78:1063-1078.

- Booth, B.D. and D.W. Larson. 1998. The role of seed rain in determining the assembly of a cliff community. *Journal of Vegetation Science* 7 366-344.
- Brodo IM, Duran-Sharnoff S, Sharnoff S (2001) *Lichens of North America*. Yale University Press, New Haven and London.
- Chung, O.S. and G.S. Jang. 2011. Estimating the habitat potential of inland forest patches for birds using a species-area curve model. *Animal Cells and Systems* 15:73-78.
- Clebsch, E.C. and G.L. Walker. 1988. Disjunct phanerogams associated with *Thuja occidentalis* in its southern disjunct range. *Castanea* 12:54-55.
- Connor, E.F. and E.D. McCoy. 1979. The statistics and biology of the species-area relationship. *American Naturalist* 13:791-833.
- de Gruchy, M.A., U. Matthes, J.A. Gerrath, and D.W. Larson. 2001. Natural recovery and restoration potential of severely disturbed talus vegetation at Niagara Falls: assessment using a reference system. *Restoration Ecology* 9 311-325.
- Farris, M.A. 1998. The effects of rock climbing on the vegetation of three Minnesota cliff systems. *Canadian Journal of Botany* 76:1981-1990.
- Haenlein, M. and Kaplan, A.M. 2004. A beginner's guide to partial least squares analysis. *Understanding Statistics* 3:283-297.
- Hellmann, J.J. and Fowler, G.W. 1999. Bias, precision, and accuracy of four measures of species richness. *Ecological Applications* 9:824-834.
- Hill, M.O. and Gaugh, H.G. 1980. Detrended correspondence analysis: an improved ordination technique. *Vegetation* 42:47-58.
- Hinkle, C.R. 1975. A preliminary study of the flora and vegetation of the Cumberland Gap National Historic Park, Middlesboro, Kentucky. [MSc Thesis]. Knoxville (TN): University of Tennessee. 236 p.
- Kuntz, K.L. and D.W. Larson. 2006. Influences on microbial constraints and rock climbing disturbance on cliff-face vegetation communities. *Conservation Biology* 20:821-832.
- Krishnamani, R. 2004. Estimating species richness at large spatial scales using data from small discrete plots. *Ecography* 27:637-642.
- Larson, D.W., U. Matthes, and P.E. Kelly. 2000. *Cliff ecology: pattern and process in cliff ecosystems*. Cambridge University Press, Cambridge, United Kingdom.
- Larson, D.W., S.H. Spring, U. Matthes-Sears, and R.M. Bartlett. 1989. *Organization*

- of the Niagara Escarpment cliff community. *Canada Journal of Botany* 67:2731-2742.
- Leitner, W.A. and Rosenzweig, M.L. 1997. Nested species-area curves and stochastic sampling: a new theory. *Oikos* 79:503-512.
- Losos, J.B. and R.E. Ricklefs. 2010. *The Theory of Island Biogeography Revisited*. Princeton University Press, Princeton, New Jersey.
- MacArthur, R.H. and E.O. Wilson. 1963. An equilibrium theory of insular zoogeography. *Evolution* 17:373-387.
- MacArthur, R.H. and E.O. Wilson. 1967. *The theory of island biogeography*. Princeton University Press, Princeton, New Jersey.
- Marui, Y., S. Chiba, J. Okuno, and K. Yamasaki. 2004. Species-area curve for land snails on Kikai Island in geologic time. *Paleobiology* 30:222-230.
- McCune, B. and Grace, J.B. 2002. *Analysis of ecological communities*. MjM Software Design, Gleneden Beach, Oregon.
- McMillan, M.A. and D.W. Larson. 2002. Effects of rock climbing on the vegetation of the Niagara Escarpment in Southern Ontario, Canada. *Conservation Biology* 16:389-398.
- Neigel, J. E. 2003. Species-area relationships and marine conservation. *Ecological Applications* 13:138-145.
- Palmer, M.W. 1990. The estimation of species richness by extrapolation. *Ecology* 72:1195-1198.
- Rice, C. L. 1984. Sandstone units of the Lee Formation and related strata in eastern Kentucky. U.S. G.P.O. Washington, D.C.
- Roberts, D.W. 1986. Ordination on the basis of fuzzy set theory. *Vegetation* 66:123-131.
- Rosenzweig, M.L. 1995. *Species diversity in space and time*. Cambridge University Press, Cambridge, United Kingdom.
- Smith, C.D. and Pontius, J.S. 2006. Jackknife estimator of species richness with S-PLUS. *Journal of Statistical Software* 15:1-12.
- Stohlgren, T.J., Falkner, M.B., and Schell, L.D. 1995. A modified-whittaker nested vegetation sampling method. *Vegetation* 117:113-121

- Stotler R, Crandall-Stotler B (1977) A checklist of the liverworts and hornworts of North America. *The Bryologist* 80:405-428
- Triantis, K.A., M. Mylonas, and R.J. Whittaker. 2008. Evolutionary species-area curve as revealed by single-island endemics: insights for the inter-provincial species area relationship. *Ecography* 31:401-407.
- Ursic, K. A., N.C. Kenkel, and D.W. Larson. 1997. Revegetation dynamics of cliff faces in abandoned limestone quarries. *Journal of Applied Ecology* 34:289-303.
- Walker, G.L. 1987. Ecology and population biology of *Thuja occidentalis* L. in its southern disjunct range. PhD Thesis, University of Tennessee, Knoxville, Tennessee.
- Walker GL, Parisher E (2005) Characterization of Plant Community Structure and Abiotic Conditions on Climbed and Unclimbed Cliff Faces in the Obed River Gorge. U.S. Department of the Interior, National Park Service. Research/ Resources Management Report. 36 p.
- Weakley A (2006) Flora of the Carolinas, Virginia, and Surrounding Area. University of North Carolina Herbarium, N.C. Botanical Garden, Chapel Hill NC.
<http://www.herbarium.unc.edu>.
- Williams, C.B. 1943. Area and number of species. *Nature* 152:264-267.

Appendix A. Summary vascular species list

Vascular

<i>Acer rubrum</i> var. <i>rubrum</i>	<i>Dichanthelium villosinum</i>	<i>Quercus alba</i>
<i>Acer saccharum</i>	<i>Diospyros virginiana</i>	<i>Quercus montana</i>
<i>Agrimonia rostellata</i>	<i>Elymus hystrix</i>	<i>Quercus rubra</i>
<i>Agrostis perennans</i>	<i>Epigaea repens</i>	<i>Quercus velutina</i>
<i>Amelanchier arborea</i>	<i>Erechtites hieraciifolius</i>	<i>Rhododendron carolinianum</i> ³
<i>Anemone acutiloba</i>	<i>Eurybia divaricata</i>	<i>Rhododendron maximum</i>
<i>Arisema triphyllum</i>	<i>Fraxinus quadrangulata</i>	<i>Rhus copallina</i>
<i>Asclepias quadrifolia</i>	<i>Galax urceolata</i>	<i>Rubus</i> cf. <i>pensylvanicus</i>
<i>Asplenium montanum</i>	<i>Galium aparine</i>	<i>Sassafras albidum</i>
<i>Asplenium ruta-muraria</i>	<i>Gaylussacia baccata</i>	<i>Sedum ternatum</i>
<i>Betula alleghaniensis</i>	<i>Glautheria procumbens</i>	<i>Silene rotundifolia</i>
<i>Betula lenta</i>	<i>Hamamelis virginiana</i>	<i>Smilax glauca</i>
<i>Bromus pubescens</i>	<i>Helianthus</i> cf. <i>microcephalus</i>	<i>Smilax rotundifolia</i>
<i>Campanula divaricata</i>	<i>Heuchera americana</i>	<i>Solidago caesia</i>
<i>Campanula divaricata</i>	<i>Heuchera</i> cf. <i>parviflora</i>	<i>Solidago flexicaulis</i>
<i>Carex</i> aff. <i>Communis</i>	<i>Houstonia longifolia</i>	<i>Symphyotrichum oblongifolium</i>
<i>Carex</i> cf. <i>pensylvanica</i>	<i>Huchera americana</i>	<i>Thalictrum thalictroides</i>
<i>Carex swanii</i>	<i>Hydatica petiolaris</i>	<i>Toxicodendron radicans</i>
<i>Carya</i> cf. <i>glabra</i>	<i>Impatiens capensis</i>	<i>Vaccinium</i> cf. <i>pallidum</i>
cf. <i>Croton/Elaeagnus</i>	<i>Kalmia latifolia</i>	<i>Vaccinium</i> cf. <i>parviflora</i>
cf. <i>Danthonia</i>	<i>Lysimachia quadrifolia</i>	<i>Vaccinium corymbosum</i>
cf. <i>Eupatorium pubescens</i>	<i>Maianthemum racemosum</i>	<i>Vaccinium fuscum</i>
cf. <i>Eurybia divaricata</i>	<i>Melanopyrum lineare</i> var. <i>latifolium</i> ²	<i>Vaccinium stamineum</i>
cf. <i>Helianthus microcephalus</i>	<i>Mitchella repens</i>	<i>Vaccinium corymbosum</i>
cf. <i>Symphyotrichum patens</i>	<i>Nyssa sylvatica</i>	<i>Viola</i> cf. <i>blanda</i>
<i>Chimiphila maculata</i>	<i>Osmundastrum cinnononea</i>	<i>Viola</i> cf. <i>sororia</i>
<i>Clematis virginiana</i>	<i>Ostrya virginiana</i>	<i>Viola hastata</i>
<i>Clethra acuminata</i>	<i>Oxalis grandis</i>	
<i>Danthonia</i> cf. <i>sericea</i>	<i>Oxydendrum aboreum</i>	
<i>Danthonia compressa</i>	<i>Oxydendrum arboreum</i>	Notes:
<i>Denstaedtia punctilobula</i>	<i>Packera obovata</i>	1. TN endangered, county record for VA, biogeographic disjunct for VA
<i>Dichanthelium</i> 1	<i>Pellaea atropurpurea</i>	2. KY Threatened
<i>Dichanthelium</i> 2	<i>Persicaria</i> cf. <i>longiseta</i>	3. State record for VA and KY
<i>Dichanthelium</i> 3	<i>Philadelphus hirsutus</i>	
<i>Dichanthelium aciculare</i> ¹	<i>Pinus virginiana</i>	
<i>Dichanthelium</i> aff. <i>Commutatum</i>	<i>Pityopsis graminifolia</i>	
<i>Dichanthelium boscii</i>	<i>Poaceae</i>	
<i>Dichanthelium depauperatum</i>	<i>Polmonia canadensis</i>	
<i>Dichanthelium dichotomum</i>	<i>Polygala senega</i>	
<i>Dichanthelium latifolium</i>	<i>Polygonatum biflorum</i> var. <i>biflorum</i>	

Appendix B. Summary bryophyte species list

Bryophyte

Andreaea rothii
Brotherella recurvans
Campylium chrysophyllum
Campylopus tallulensis
Cephalozia sp.
Ceratodon cf. *purpureus*
cf. *Anomodon rostratus*
cf. *Dicranum flagellare*
cf. *Pylaisella* sp.
Dicranodontium denudatum
Dicranum condensatum
Dicranum fuscescens
Dicranum montanum
Ephebe lanata
Fissidens taxifolius
Hedwigia ciliata
Hypnum imponens
Hypnum pallescens
Isopterygium elegans
Lepraria membranacea
Leucobryum albidum
Leucobryum glaucum
Platygyrium repens
Polytrichum juniperinum
Polytrichum ohioense
Pylaisiadelphina tenuirostris
Racomitrium cf. *heterostichum*
Schistidium cf. *apocarpum*
Schistidium rivulare
Sematophyllum demissum
Sphagnum sp.
Taxiphyllum deplanatum
Tortella humilis

Liverworts

Cephaloziella sp.
Diplophyllum apiculatum
Frullania riparia
Scapania nemorea

Appendix C. Summary lichen species list

Lichens

<i>Amandinea punctata</i>	<i>Micarea peliocarpa</i>
<i>Bryoria nadvornikiana</i>	<i>Nostoc</i>
<i>Buellia spuria</i>	<i>Ochrolechia sp.</i>
<i>Buellia stillingiana</i>	<i>Panaparmelia alabamensis</i>
<i>Caloplaca citrina</i>	<i>Paraparmelia alabamensis</i>
<i>Campylopus tallulensis</i>	<i>Parmelia squarrosa</i>
<i>Canoparmelia crozalsiana</i>	<i>Parmelinopsis minarum</i>
<i>Chroococcus</i>	<i>Parmotrema</i>
<i>Chrysothrix</i>	<i>Peltula sp.</i>
<i>Cladonia caespitica</i>	<i>Pertusaria amara</i>
<i>Cladonia cenotea</i>	<i>Pertusaria plittiana</i>
<i>Cladonia parasitica</i>	<i>Pertusaria rubefacta</i>
<i>Cladonia petrophila</i>	<i>Phaeophyscia adiastrata</i>
<i>Cladonia pocillum</i> ⁴	<i>Phaeophyscia ciliata</i>
<i>Cladonia rangiferina</i>	<i>Phaeophyscia sciastra</i>
<i>Cladonia squamosa</i>	<i>Phlyctis argena</i>
<i>Cladonia strepsilis</i>	<i>Physcia aipolia</i>
<i>Cladonia subtenuis</i>	<i>Physcia subtilis</i>
<i>Cladonia symphyllaria</i>	<i>Physciella chloantha</i>
<i>Dicranodontium denudatum</i>	<i>Physciella melanchra</i>
<i>Dimelaena oreina</i>	<i>Physonica</i>
<i>Diploschistes scruposus</i>	<i>Pleopsidium flavum</i>
<i>Ephebe lanata</i>	<i>Polysporina simplex</i>
<i>Flavoparmelia baltimorensis</i>	<i>Protoblastenia rupestris</i>
<i>Heterodermia speciosa</i>	<i>Ramalina obtusata</i>
<i>Imshaugia aleurites</i>	<i>Ramalina pollinaria</i>
<i>Lasallia papulosa</i>	<i>Rhizocarpon badioatrum</i>
<i>Lasallia pensylvanica</i>	<i>Rhizocarpon disporum</i>
<i>Lecanora oreinoides</i>	<i>Rhizocarpon hochstetteri</i>
<i>Lecanora thysanophora</i>	<i>Rhizocarpon obscuratum</i>
<i>Lepraria elobata</i>	<i>Sarcogyne regularis</i>
<i>Lepraria lobifera</i>	<i>Trentepohlia sp.</i>
<i>Lepraria membranacea</i>	<i>Tripe rugosa</i>
<i>Lepraria neglecta</i>	<i>Umbilicaria mammulata</i>
<i>Lepraria rigidula</i>	<i>Umbilicaria virginis</i>
<i>Leptoloma membranacea</i>	<i>Usnea amblyoclada</i>
<i>Leptogium chloromelum</i>	<i>Usnea halei</i>
<i>Leptogium lichenoides</i>	<i>Verrucaria calciseda</i>
<i>Melanelia culbersonii</i>	<i>Xanthoria sorediata</i>
<i>Melanelia disjuncta</i>	
<i>Melanelia panniformis</i>	
<i>Melanelia sorediata</i>	

Notes:

4. Artic/boreal disjunct

Appendix D. Species list by transect

Transect name	Latitude	Group	Species	Listing	Position
Lower Chadwell T1	36.66701202	Vascular	<i>Betula alleghaniensis</i>	n/a	Cliff
	Longitude	Vascular	<i>Rhododendron maximum</i>	n/a	Edge
	-83.50936197	Vascular	<i>Smilax rotundifolia</i>	n/a	Talus
		Vascular	<i>Vaccinium corymbosum</i>	n/a	Cliff
		Vascular	<i>Vaccinium pallidum</i>	n/a	Cliff
		Moss	<i>Campylopus tallulis</i>	n/a	Cliff
		Moss	<i>Diplophyllum apiculatum</i>	n/a	Talus
		Moss	<i>Leucobryum albidum</i>	n/a	Cliff
		Moss	<i>Leucobryum cf. glaucum</i>	n/a	Edge
		Lichen	<i>Buellia spuria</i>	n/a	Cliff
		Lichen	<i>Cladonia strepsilis</i>	n/a	Cliff
		Lichen	<i>Diploschistes scruposus</i>	n/a	Cliff
		Lichen	<i>Lasallia papulosa</i>	n/a	Edge
		Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
		Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
		Lichen	<i>Lepraria neglecta</i>	n/a	Cliff
		Lichen	<i>Leucobryum glaucum</i>	n/a	Cliff
		Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
		Lichen	<i>Phaeophyscia adiastrum</i>	n/a	Edge
		Lichen	<i>Umbilicaria mammulata</i>	n/a	Edge

Transect name	Latitude	Group	Species	Listing	Position
Lower Chadwell T2	36.66714999	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Cliff
	Longitude	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Cliff
	-83.50942299	Vascular	<i>cf. eurybia divaricata</i>	n/a	Cliff
		Vascular	<i>Clethra acuminata</i>	n/a	Cliff
		Vascular	<i>Danthonia compressa</i>	n/a	Cliff
		Vascular	<i>Galax urceolata</i>	n/a	Cliff
		Vascular	<i>Mitchella repens</i>	n/a	Cliff
		Vascular	<i>Poaceae</i>	n/a	Cliff
		Vascular	<i>Rhododendron maximum</i>	n/a	Edge
		Vascular	<i>Vaccinium cf. corymbosum</i>	n/a	Cliff
		Vascular	<i>Vaccinium cf.</i>	n/a	Cliff

		<i>pallidum</i>		
Moss		<i>Andreaea rothii</i>	n/a	Cliff
Moss		<i>Brotherella recurvans</i>	n/a	Edge
Moss		<i>Dicranodontium denudatum</i>	n/a	Cliff
Moss		<i>Ephebe lanata</i>	n/a	Cliff
Moss		<i>Leucobryum cf. albidum</i>	n/a	Cliff
Moss		<i>Racomitrium cf. heterostichum</i>	n/a	Cliff
Moss		<i>Scapania nemorea</i>	n/a	Cliff
Moss		<i>Sematophyllum demissum</i>	n/a	Cliff
Lichen		<i>Diploschistes scruposus</i>	n/a	Cliff
Lichen		<i>Lepraria membranacea</i>	n/a	Cliff
Lichen		<i>Melanelia culbersonii</i>	n/a	Edge
Lichen		<i>Melanelia panniformis</i>	n/a	Cliff
Lichen		<i>Melanelia soorediata</i>	n/a	Cliff
Lichen		<i>Micarea peliocarpa</i>	n/a	Edge
Lichen		<i>Physcia aipola</i>	n/a	Cliff
Lichen		<i>Trentepohlia</i>	n/a	Cliff
Lichen		<i>Umbilicaria mammulata</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Lower Chadwell T3	36.66691798	Vascular	<i>Acer rubrum var. rubrum</i>	n/a	Cliff
		Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	-83.509166	Vascular	<i>Betula alleghaniensis</i>	n/a	Cliff
		Vascular	<i>cf. Smilax rotundifolia</i>	n/a	Talus
		Vascular	<i>Dichanthium villosinum</i>	n/a	Cliff
		Vascular	<i>Heuchera cf. parviflora</i>	n/a	Cliff
		Vascular	<i>Kalmia latifolia</i>	n/a	Talus
		Vascular	<i>Rhododendron maximum</i>	n/a	Cliff
		Vascular	<i>Vaccinium stamineum</i>	n/a	Cliff
		Moss	<i>Lepraria lobificans</i>	n/a	Cliff
		Moss	<i>Leucobryum albidum</i>	n/a	Talus
		Lichen	<i>Diploschistes scruposus</i>	n/a	Cliff
		Lichen	<i>Ephebe lanata</i>	n/a	Cliff
		Lichen	<i>Lapraria sp.</i>	n/a	Cliff

		Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
		Lichen	<i>Lepraria elobata</i>	n/a	Cliff
		Lichen	<i>Melanelia disjuncta</i>	n/a	Cliff
		Lichen	<i>Phlyctis argena</i>	n/a	Cliff
		Lichen	<i>Usnea halei</i>	n/a	Cliff
Transect name	Latitude	Group	Species	Listing	Position
Upper Chadwell T4	36.668403	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Edge
	Longitude	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Edge
	-83.50812899	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
		Vascular	<i>Gaylussacia baccata</i>	n/a	Edge
		Vascular	<i>Melanpyrum lineare</i> var. <i>latifolium</i>	KY Threatened	Talus
		Vascular	<i>Polygonatum biflorum</i> var. <i>biflorum</i>	n/a	Edge
		Vascular	<i>Quercus montana</i>	n/a	Edge
		Moss	cf. <i>Dicranodontium denudatum</i>	n/a	Talus
		Moss	cf. <i>Pylaisella</i> sp.	n/a	Talus
		Moss	<i>Isopterygium elegans</i>	n/a	Cliff
		Moss	<i>Leucobryum albidum</i>	n/a	Edge
		Lichen	<i>Heterodermia speciosa</i>	n/a	Edge
		Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
		Lichen	<i>Lepraria</i>	n/a	Cliff
		Lichen	<i>melanelia culbersonii</i>	n/a	Cliff
		Lichen	<i>Ochrolechia</i>	n/a	Cliff
		Lichen	<i>Pertusaria amara</i>	n/a	Edge
		Lichen	<i>Pertusaria rubefacta</i>	n/a	Cliff
		Lichen	<i>Phaeophyscia sciastra</i>	n/a	Edge
		Lichen	<i>Phlyctis argena</i>	n/a	Cliff
		Lichen	<i>Usnea halei</i>	n/a	Cliff
Transect name	Latitude	Group	Species	Listing	Position
Upper Chadwell T5	36.66848497	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Edge
	Longitude	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Edge
	-83.50802497	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
		Vascular	<i>Chimiphila maculata</i>	n/a	Edge
		Vascular	<i>Danthonia compressa</i>	n/a	Edge
		Vascular	<i>Melanpyrum lineare</i> var. <i>latifolium</i>	KY Threatened	Edge

Vascular	<i>Mitchella repens</i>	n/a	Talus
Vascular	<i>Osmundastrum cinnononea</i>	n/a	Cliff
Vascular	<i>Quercus rubra</i>	n/a	Talus
Vascular	<i>Sassafrass albidum</i>	n/a	Talus
Vascular	<i>Smilax glauca</i>	n/a	Edge
Moss	<i>Dicranodontium denudatum</i>	n/a	Talus
Moss	<i>Dicranum fuscescens</i>	n/a	Edge
Moss	<i>Hedwigia ciliata</i>	n/a	Talus
Moss	<i>Leucobryum albidum</i>	n/a	Edge
Moss	<i>Taxiphyllum deplanatum</i>	n/a	Cliff
Lichen	<i>Amandinea punctata</i>	n/a	Cliff
Lichen	<i>Buellia spuria</i>	n/a	Cliff
Lichen	<i>Canoparmelia crozalsiana</i>	n/a	Edge
Lichen	<i>Chrysothrix</i>	n/a	Cliff
Lichen	<i>Cladonia parasitica</i>	n/a	Talus
Lichen	<i>Cladonia rangiferina</i>	n/a	Edge
Lichen	<i>Cladonia subtenuis</i>	n/a	Edge
Lichen	<i>Melanelia disjuncta</i>	n/a	Cliff
Lichen	<i>Pertusaria amara</i>	n/a	Cliff
Lichen	<i>Ramalina obtusata</i>	n/a	Cliff
Lichen	<i>Umbilicaria mammulata</i>	n/a	Edge
Lichen	<i>Usnea amblyoclada</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Teaberry T6	36.66826	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
		Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	-83.51293802	Vascular	<i>Betula cf. lenta</i>	n/a	Cliff
		Vascular	<i>cf. Smilax rotundifolia</i>	n/a	Edge
		Vascular	<i>Galax urceolata</i>	n/a	Edge
		Vascular	<i>Glaultheria procumbens</i>	n/a	Edge
		Vascular	<i>Sassafrass albidum</i>	n/a	Edge
		Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
		Lichen	<i>Lepraria membranacea</i>	n/a	Cliff
		Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
		Lichen	<i>Parmelia squarrosa</i>	n/a	Cliff
		Lichen	<i>Parmelinopsis minarum</i>	n/a	Cliff
		Lichen	<i>Pertusaria plittiana</i>	n/a	Cliff

		Lichen	<i>Physcia subtilis</i>	n/a	Cliff
		Lichen	<i>Polysporina simplex</i>	n/a	Cliff
		Lichen	<i>Rhizocarpon obscuratum</i>	n/a	Cliff
		Lichen	<i>Sarcogyne regularis</i>	n/a	Cliff
		Lichen	<i>Umbilicaria mammulata</i>	n/a	Cliff
Transect name	Latitude	Group	Species	Listing	Position
Teaberry T7	36.66783202	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Edge
	Longitude	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	-83.51348402	Vascular	<i>Carex</i> 3	n/a	Cliff
		Vascular	<i>cf. Smilax rotundifolia</i>	n/a	Edge
		Vascular	<i>Danthonia compressa</i>	n/a	Talus
		Vascular	<i>Danthonia sericea</i>	n/a	Cliff
		Vascular	<i>Denstaedtia punctilobula</i>	n/a	Talus
		Vascular	<i>Dichanthium</i> 1	n/a	Cliff
		Vascular	<i>Dichanthium</i> 2	n/a	Cliff
		Vascular	<i>Dichanthium dichotomum</i>	n/a	Cliff
		Vascular	<i>Galax urceolata</i>	n/a	Edge
		Vascular	<i>Gaulthera procumbens</i>	n/a	Edge
		Vascular	<i>Hamamelis virginiana</i>	n/a	Talus
		Vascular	<i>Hydratica petiolaris</i>	n/a	Cliff
		Vascular	<i>Mitchella repens</i>	n/a	Cliff
		Vascular	<i>Oxydendrum aboreum</i>	n/a	Talus
		Vascular	<i>Rhododendron maximum</i>	n/a	Cliff
		Vascular	<i>Vaccinium cf. pallidum</i>	n/a	Cliff
		Vascular	<i>Vaccinium corymbosum</i>	n/a	Cliff
		Moss	<i>Campylopus tallulensis</i>	n/a	Cliff
		Moss	<i>cf. Ceratodon purpureus</i>	n/a	Cliff
		Moss	<i>Racomitrium heterostichum</i>	n/a	Cliff
		Moss	<i>Sphagnum</i>	n/a	Talus
		Lichen	<i>Buellia spuria</i>	n/a	Cliff
		Lichen	<i>Cladonia pocillum</i>	Artic/boreal disjunct	Cliff
		Lichen	<i>Diploschistes scruposus</i>	n/a	Cliff

		Lichen	<i>Lasallia papulosa</i>	n/a	Cliff
		Lichen	<i>Lepraria membranacea</i>	n/a	Cliff
		Lichen	<i>Lepraria membranaceum</i>	n/a	Cliff
		Lichen	<i>Lepraria neglecta</i>	n/a	Cliff
		Lichen	<i>Leptogium chloromelum</i>	n/a	Cliff
		Lichen	<i>Parmelia squarrosa</i>	n/a	Cliff
		Lichen	<i>Rhizocarpon disporum</i>	n/a	Cliff
		Lichen	<i>Trentepohlia</i>	n/a	Cliff
Transect name	Latitude	Group	Species	Listing	Position
Teaberry T8	36.66870802	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Edge
	Longitude	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	-83.51264197	Vascular	<i>Carya</i>	n/a	Edge
		Vascular	cf. <i>Smilax rotundifolia</i>	n/a	Edge
		Vascular	<i>Gaylussacia baccata</i>	n/a	Edge
		Vascular	<i>Nyssa sylvatica</i>	n/a	Edge
		Vascular	<i>Polygonatum biflorum</i> var. <i>biflorum</i>	n/a	Edge
		Vascular	<i>Rhododendron maximum</i>	n/a	Cliff
		Vascular	<i>Vaccinium</i> cf. <i>pallidum</i>	n/a	Cliff
		Vascular	<i>Vaccinium pallidum</i>	n/a	Edge
		Vascular	<i>Vaccinium stamineum</i>	n/a	Cliff
		Moss	<i>Campylopus tallulensis</i>	n/a	Cliff
		Moss	<i>Leucobryum</i>	n/a	Cliff
		Moss	<i>Leucobryum albidum</i>	n/a	Cliff
		Moss	<i>Leucobryum</i> sp.	n/a	Cliff
		Lichen	<i>Cladonia pocillum</i>	Artic/boreal disjunct	Cliff
		Lichen	<i>Imshaugia aleurites</i>	n/a	Cliff
		Lichen	<i>Lasallia papulosa</i>	n/a	Cliff
		Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
		Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
		Lichen	<i>Lepraria membranacea</i>	n/a	Cliff
		Lichen	<i>Lepraria neglecta</i>	n/a	Cliff
		Lichen	<i>Lepraria rigidula</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Teaberry T9	36.66853501	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Edge
		Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	-83.51233704	Vascular	<i>Betula alleghaniensis</i>	n/a	Cliff
		Vascular	<i>Clethra acuminata</i>	n/a	Cliff
		Vascular	<i>Dichanthelium</i> aff. <i>Commutatum</i>	n/a	Cliff
		Vascular	<i>Dichanthelium boscii</i>	n/a	Cliff
		Vascular	<i>Gaultheria procumbens</i>	n/a	Edge
		Vascular	<i>Kalmia latifolia</i>	n/a	Cliff
		Vascular	<i>Leucobryum glaucum</i>	n/a	Edge
		Vascular	<i>Lysimachia quadrifolia</i>	n/a	Edge
		Vascular	<i>Melampyrum lineare</i> var. <i>latifolium</i>	n/a	Edge
		Vascular	<i>Rhododendron maximum</i>	n/a	Edge
		Vascular	<i>Sassafras albidum</i>	n/a	Edge
		Vascular	<i>Smilax rotundifolia</i>	n/a	Edge
		Moss	<i>Campylopus tallulensis</i>	n/a	Cliff
		Lichen	<i>Cladonia petrophila</i>	n/a	Cliff
		Lichen	<i>Cladonia pocillum</i>	Artic/boreal disjunct	Cliff
		Lichen	<i>Imshaugia aleurites</i>	n/a	Cliff
		Lichen	<i>Lasallia papulosa</i>	n/a	Cliff
		Lichen	<i>Lepraria membranacea</i>	n/a	Cliff
		Lichen	<i>Lepraria membranaceum</i>	n/a	Cliff
		Lichen	<i>Leproloma membranacea</i>	n/a	Cliff
		Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
		Lichen	<i>Panaparmelia alabamensis</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
West Chadwell T10	36.65472399	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Edge
		Vascular	<i>Arisema triphyllum</i>	n/a	Cliff
	-83.54568101	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
		Vascular	<i>Betula alleghaniensis</i>	n/a	Cliff
		Vascular	<i>Danthonia sericea</i>	n/a	Cliff
		Vascular	<i>Dichanthelium depauperatum</i>	n/a	Cliff

Vascular	<i>Dichanthelium dichotomum</i>	n/a	Cliff
Vascular	<i>Epigaea repens</i>	n/a	Cliff
Vascular	<i>Galax urceolata</i>	n/a	Cliff
Vascular	<i>Gaultheria procumbens</i>	n/a	Edge
Vascular	<i>Hamamelis virginiana</i>	n/a	Edge
Vascular	<i>Oxydendrum arboreum</i>	n/a	Cliff
Vascular	<i>Quercus rubra</i>	n/a	Edge
Vascular	<i>Rhododendron maximum</i>	n/a	Edge
Vascular	<i>Sassafras albidum</i>	n/a	Edge
Vascular	<i>Vaccinium cf. corymbosum</i>	n/a	Cliff
Vascular	<i>Vaccinium cf. pallidum</i>	n/a	Cliff
Vascular	<i>Vaccinium stamineum</i>	n/a	Cliff
Moss	<i>Campylopus tallulensis</i>	n/a	Cliff
Moss	<i>Leucobryum albidum</i>	n/a	Edge
Lichen	<i>Amelanchier arborea</i>	n/a	Cliff
Lichen	<i>Dimelaena oreina</i>	n/a	Cliff
Lichen	<i>Lecanora thysanophora</i>	n/a	Cliff
Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
Lichen	<i>Lepraria membranacea</i>	n/a	Cliff
Lichen	<i>Lepraria neglecta</i>	n/a	Cliff
Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
Lichen	<i>Parmelia squarrosa</i>	n/a	Cliff
Lichen	<i>Phaeophyscia</i>	n/a	Cliff
Lichen	<i>Physciella chloantha</i>	n/a	Cliff
Lichen	<i>Umbilicaria mammulata</i>	n/a	Cliff
Lichen	<i>Usnea amblyoclada</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
West Chadwell T11	36.65463899	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Talus
		Vascular	<i>Amelanchier arborea</i>	n/a	Edge
	-83.54567899	Vascular	<i>Carya</i>	n/a	Talus
		Vascular	<i>Gaylussacia baccata</i>	n/a	Edge
		Vascular	<i>Kalmia latifolia</i>	n/a	Edge
		Vascular	<i>Pinus virginiana</i>	n/a	Edge

Vascular	<i>Smilax rotundifolia</i>	n/a	Talus
Moss	<i>Campylopus tallulensis</i>	n/a	Edge
Moss	<i>Dicranum montanum</i>	n/a	Cliff
Lichen	<i>Campylopus tallulensis</i>	n/a	Cliff
Lichen	<i>Cladonia caespitica</i>	n/a	Edge
Lichen	<i>Cladonia cenotea</i>	n/a	Cliff
Lichen	<i>Cladonia symphyrcarpia</i>	n/a	Cliff
Lichen	<i>Dimelaena oreina</i>	n/a	Cliff
Lichen	<i>Diploschistes scruposus</i>	n/a	Cliff
Lichen	<i>Lasallia papulosa</i>	n/a	Cliff
Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
Lichen	<i>Physcia halei</i>	n/a	Cliff
Lichen	<i>Usnea amblyoclada</i>	n/a	Edge

Transect name	Latitude	Group	Species	Listing	Position
Indian Rocks T12	36.66506097	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
		Vascular	<i>Betula alleghaniensis</i>	n/a	Talus
	-83.53063197	Vascular	<i>Dennstaedtia punctilobula</i>	n/a	Talus
		Vascular	<i>Diospyros virginiana</i>	n/a	Talus
		Vascular	<i>Galax urceolata</i>	n/a	Edge
		Vascular	<i>Gaylussacia baccata</i>	n/a	Edge
		Vascular	<i>Melampyrum lineare</i> var. <i>latifolium</i>	n/a	Edge
		Vascular	<i>Smilax rotundifolia</i>	n/a	Edge
		Moss	<i>Dicranum montanum</i>	n/a	Cliff
		Lichen	<i>Bryoria nadvornikiana</i>	n/a	Cliff
		Lichen	<i>Flavoparmelia baltimorensis</i>	n/a	Cliff
		Lichen	<i>Lasallia papulosa</i>	n/a	Cliff
		Lichen	<i>Lepraria neglecta</i>	n/a	Cliff
		Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
		Lichen	<i>Micarea peliocarpa</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Indian Rocks T13	36.66506097	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
		Vascular	<i>Danthonia compressa</i>	n/a	Talus
	-83.53063197	Vascular	<i>Dennstaedtia punctilobula</i>	n/a	Talus
		Vascular	<i>Galax urceolata</i>	n/a	Edge

Vascular	<i>Gaylussacia baccata</i>	n/a	Edge
Vascular	<i>Kalmia latifolia</i>	n/a	Talus
Vascular	<i>Melampyrum lineare</i> var. <i>latifolium</i>	n/a	Edge
Vascular	<i>Quercus montana</i>	n/a	Talus
Vascular	<i>Quercus velutina</i>	n/a	Talus
Vascular	<i>Rhododendron</i> <i>maximum</i>	n/a	Talus
Vascular	<i>Rubus cf.</i> <i>pensylvanicus</i>	n/a	Talus
Vascular	<i>Smilax rotundifolia</i>	n/a	Edge
Vascular	<i>Viola cf. sororia</i>	n/a	Talus
Vascular	<i>Viola hastata</i>	n/a	Talus
Moss	<i>Andreaea rothii</i>	n/a	Cliff
Moss	<i>Tortella humilis</i>	n/a	Cliff
Lichen	<i>Cladonia squamosa</i>	n/a	Cliff
Lichen	<i>Lepraria</i> <i>membranaceum</i>	n/a	Cliff
Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
Lichen	<i>Ramalina pollinaria</i>	n/a	Cliff
Lichen	<i>Umbilicaria</i> <i>mammulata</i>	n/a	Cliff
Lichen	<i>Usnea halei</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Skylight Cave T14	36.61549903	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Talus
	Longitude	Vascular	<i>Acer saccharum</i>	n/a	Edge
	-83.64346303	Vascular	<i>Agrimonia rostellata</i>	n/a	Edge
		Vascular	<i>Anemone acutiloba</i>	n/a	Edge
		Vascular	<i>Bromus pubescens</i>	n/a	Cliff
		Vascular	<i>Carex aff. Communis</i>	n/a	Edge
		Vascular	<i>Carya cf. glabra</i>	n/a	Edge
		Vascular	<i>Clematis virginiana</i>	n/a	Talus
		Vascular	<i>Fraxinus</i> <i>quadrangulata</i>	n/a	Edge
		Vascular	<i>Hamamelis</i> <i>virginiana</i>	n/a	Edge
		Vascular	<i>Houstonia longifolia</i>	n/a	Cliff
		Vascular	<i>Huchera americana</i>	n/a	Cliff
		Vascular	<i>Impatiens capensis</i>	n/a	Talus
		Vascular	<i>Ostrya virginiana</i>	n/a	Edge
		Vascular	<i>Oxalis grandis</i>	n/a	Edge
		Vascular	<i>Packera cf. obovata</i>	n/a	Cliff
		Vascular	<i>Packera obovata</i>	n/a	Edge
		Vascular	<i>Pellaea atropurpurea</i>	n/a	Cliff

Vascular	<i>Philadelphus hirsutus</i>	n/a	Cliff
Vascular	<i>Polmnia canadensis</i>	n/a	Cliff
Vascular	<i>Polygala senega</i>	n/a	Edge
Vascular	<i>Polymnia canadensis</i>	n/a	Talus
Vascular	<i>Quercus rubra</i>	n/a	Edge
Vascular	<i>Sedum ternatum</i>	n/a	Cliff
Vascular	<i>Thalictrum thalictroides</i>	n/a	Edge
Vascular	<i>Toxicodendron radicans</i>	n/a	Edge
Vascular	<i>Viola cf. sororia</i>	n/a	Cliff
Moss	<i>Campylium chrysophyllum</i>	n/a	Edge
Moss	<i>cf. Pylaisiella</i>	n/a	Cliff
Moss	<i>Fissidens taxifolius</i>	n/a	Edge
Moss	<i>Schistidium rivulare</i>	n/a	Cliff
Lichen	<i>Caloplaca citrina</i>	n/a	Cliff
Lichen	<i>Chroococcus</i>	n/a	Cliff
Lichen	<i>Lepraria membranacea</i>	n/a	Cliff
Lichen	<i>Lepraria membranaceum</i>	n/a	Cliff
Lichen	<i>Leptogium lichenoides</i>	n/a	Cliff
Lichen	<i>Protoblastenia rupestris</i>	n/a	Edge
Lichen	<i>Rhizocarpon hochstetteri</i>	n/a	Cliff
Lichen	<i>Trentepohlia</i>	n/a	Cliff
Lichen	<i>Umbilicaria mammulata</i>	n/a	Cliff
Lichen	<i>Verrucaria calciseda</i>	n/a	Edge
Lichen	<i>Xanthoria soorediata</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Skylight Cave T15	36.615148	Vascular	<i>Asclepias quadrifolia</i>	n/a	Edge
		Vascular	<i>Asplenium ruta-muraria</i>	n/a	Edge
	-83.643202	Vascular	<i>Bromus pubescens</i>	n/a	Edge
		Vascular	<i>Carex 4</i>	n/a	Edge
		Vascular	<i>cf. Helianthus microcephalus</i>	n/a	Edge
		Vascular	<i>Hamamelis virginiana</i>	n/a	Talus
		Vascular	<i>Maianthemum racemosum</i>	n/a	Talus
		Vascular	<i>Packera obovata</i>	n/a	Edge

Vascular	<i>Parmelia squarrosa</i>	n/a	Edge
Vascular	<i>Pellaea atropurpurea</i>	n/a	Edge
Vascular	<i>Sedum ternatum</i>	n/a	Edge
Vascular	<i>Solidago flexicaulis</i>	n/a	Talus
Vascular	<i>Toxicodendron radicans</i>	n/a	Edge
Vascular	<i>Viola cf. sororia</i>	n/a	Edge
Moss	<i>Schistidium cf. apocarpum</i>	n/a	Cliff
Moss	<i>Schistidium rivulare</i>	n/a	Edge

Transect name	Latitude	Group	Species	Listing	Position
Pinnacle Overlook T16	36.60511896	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
		Longitude			
	-83.66714702	Vascular	<i>Betula lenta</i>	n/a	Edge
		Vascular	<i>Dichanthelium depauperatum</i>	n/a	Cliff
		Vascular	<i>Oxydendrum arboreum</i>	n/a	Edge
		Vascular	<i>Pinus virginiana</i>	n/a	Edge
		Vascular	<i>Sassafras albidum</i>	n/a	Talus
		Vascular	<i>Smilax rotundifolia</i>	n/a	Talus
		Vascular	<i>Vaccinium stamineum</i>	n/a	Cliff
		Moss	<i>Campylopus tallulensis</i>	n/a	Talus
		Moss	<i>Pylaisiadelphina tenuirostris</i>	n/a	Cliff
		Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
		Lichen	<i>Lecanora oreinoides</i>	n/a	Edge
		Lichen	<i>Lecanora thysanophora</i>	n/a	Cliff
		Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
		Lichen	<i>Leucobryum cf. albidum</i>	n/a	Cliff
		Lichen	<i>Melanelia culbersonii</i>	n/a	Edge
		Lichen	<i>Parmelia squarrosa</i>	n/a	Edge

Transect name	Latitude	Group	Species	Listing	Position
Pinnacle Overlook T17	36.60512298	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Cliff
		Longitude			
	-83.66720402	Vascular	<i>Amelanchier arborea</i>	n/a	Cliff
		Vascular	<i>Asplenium montanum</i>	n/a	Cliff
		Vascular	<i>Betula alleghaniensis</i>	n/a	Cliff
		Vascular	<i>Carya cf. glabra</i>	n/a	Talus
		Vascular	<i>cf. Eupatorium pubescens</i>	n/a	Talus

Vascular	<i>Danthonia compressa</i>	n/a	Talus
Vascular	<i>Dichantheium aciculare</i>	TN endangered, county record for VA, biogeographi c disjunct for VA	Edge
Vascular	<i>Dichantheium depauperatum</i>	n/a	Edge
Vascular	<i>Pinus virginiana</i>	n/a	Cliff
Vascular	<i>Pityopsis graminifolia</i>	n/a	Edge
Vascular	<i>Quercus cf. rubra</i>	n/a	Talus
Vascular	<i>Quercus cf. velutina</i>	n/a	Talus
Vascular	<i>Rhus copallina</i>	n/a	Edge
Vascular	<i>Smilax rotundifolia</i>	n/a	Edge
Vascular	<i>Toxicodendron radicans</i>	n/a	Talus
Moss	<i>Leucobryum albidum</i>	n/a	Talus
Moss	<i>Leucobryum cf. albidum</i>	n/a	Cliff
Moss	<i>Polytrichum ohioense</i>	n/a	Cliff
Lichen	<i>Lasallia papulosa</i>	n/a	Edge
Lichen	<i>Lecanora thysanophora</i>	n/a	Cliff
Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
Lichen	<i>Lepraria membranacea</i>	n/a	Cliff
Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
Lichen	<i>Parmelia squarrosa</i>	n/a	Cliff
Lichen	<i>Pertusaria plittiana</i>	n/a	Cliff
Lichen	<i>Physcia subtilis</i>	n/a	Edge
Lichen	<i>Rhizocarpon badioatrum</i>	n/a	Cliff
Lichen	<i>Rhizocarpon obscuratum</i>	n/a	Cliff
Lichen	<i>Usnea halei</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Pinnacle Overlook T18	36.60508099	Vascular	<i>Betula alleghaniensis</i>	n/a	Edge
		Vascular	<i>Betula lenta</i>	n/a	Talus
	-83.66719304	Vascular	<i>Oxydendrum arboreum</i>	n/a	Edge
		Vascular	<i>Pinus virginiana</i>	n/a	Edge
		Vascular	<i>Vaccinium cf. pallidum</i>	n/a	Talus
		Lichen	<i>Amandinea punctata</i>	n/a	Edge

Lichen	<i>Buellia spuria</i>	n/a	Cliff
Lichen	<i>Buellia stillingiana</i>	n/a	Cliff
Lichen	<i>Cladonia</i>	n/a	Cliff
Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
Lichen	<i>Lepraria membranacea</i>	n/a	Edge
Lichen	<i>Melanelia culbersonii</i>	n/a	Edge
Lichen	<i>Parmelinopsis minarum</i>	n/a	Cliff
Lichen	<i>Phaeophyscia ciliata</i>	n/a	Cliff
Lichen	<i>Umbilicaria mammulata</i>	n/a	Cliff
Lichen	<i>Usnea amblyoclada</i>	n/a	Talus

Transect name	Latitude	Group	Species	Listing	Position
Pinnacle Overlook T19	36.60510303	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	Longitude	Vascular	<i>Dichanthelium aciculare</i>	TN endangered, county record for VA, biogeographic disjunct for VA	Edge
	-83.66719899	Vascular	<i>Pinus virginiana</i>	n/a	Cliff
		Vascular	<i>Sassafras albidum</i>	n/a	Talus
		Vascular	<i>Vaccinium cf. pallidum</i>	n/a	Talus
		Moss	<i>cf. Ceratodon purpureus</i>	n/a	Edge
		Lichen	<i>Cladonia</i>	n/a	Edge
		Lichen	<i>Diploschistes scruposus</i>	n/a	Cliff
		Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
		Lichen	<i>Lepraria lobifcans</i>	n/a	Cliff
		Lichen	<i>Lepraria membranacea</i>	n/a	Edge
		Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
		Lichen	<i>Parmelinopsis minarum</i>	n/a	Edge
		Lichen	<i>Physcia aipolia</i>	n/a	Cliff
		Lichen	<i>Pleopsidium flavum</i>	n/a	Cliff
		Lichen	<i>Rhizocarpon disporum</i>	n/a	Edge
		Lichen	<i>Usnea halei</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Ridge Trail	36.60574299	Vascular	<i>Acer rubrum var.</i>	n/a	Cliff

T20

rubrum

Longitude	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
-83.66702498	Vascular	<i>Betula alleghaniensis</i>	n/a	Cliff
	Vascular	<i>Carex 2</i>	n/a	Edge
	Vascular	<i>Dichanthelium 3</i>	n/a	Edge
	Vascular	<i>Diospyros virginiana</i>	n/a	Edge
	Vascular	<i>Quercus alba</i>	n/a	Talus
	Moss	<i>Leucobryum albidum</i>	n/a	Edge
	Lichen	<i>Buellia spuria</i>	n/a	Edge
	Lichen	<i>Cladonia</i>	n/a	Cliff
	Lichen	<i>Lecanora</i>	n/a	Cliff
		<i>thysanophora</i>		
	Lichen	<i>Lepraria</i>	n/a	Edge
		<i>membranacea</i>		
	Lichen	<i>Peltula</i>	n/a	Cliff
	Lichen	<i>Tripe rugosa</i>	n/a	Edge
	Lichen	<i>Usnea halei</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Ridge Trail	36.60578398	Vascular	<i>Acer rubrum</i> var.	n/a	Edge
T21			<i>rubrum</i>		
	Longitude	Vascular	<i>Betula alleghaniensis</i>	n/a	Cliff
	-83.66677	Vascular	<i>Carex cf.</i>	n/a	Edge
			<i>pennsylvanica</i>		
		Vascular	<i>Carex swanii</i>	n/a	Talus
		Vascular	<i>cf. Croton/Elaeagnus</i>	n/a	Cliff
		Vascular	<i>cf. Solidago caesia</i>	n/a	Talus
		Vascular	<i>cf. Symphyotrichum</i>	n/a	Talus
			<i>patens</i>		
		Vascular	<i>Danthonia compressa</i>	n/a	Talus
		Vascular	<i>Dichanthelium</i>	n/a	Edge
			<i>dichotomum</i>		
		Vascular	<i>Erechtites</i>	n/a	Edge
			<i>hieracitifolius</i>		
		Vascular	<i>Heuchera americana</i>	n/a	Talus
		Vascular	<i>Persicaria cf.</i>	n/a	Talus
			<i>longiseta</i>		
		Vascular	<i>Rhododendron</i>	State record	Cliff
			<i>carolinianum</i>	for VA and KY	
		Vascular	<i>Rubus cf.</i>	n/a	Talus
			<i>pennsylvanicus</i>		
		Vascular	<i>Smilax rotundifolia</i>	n/a	Talus
		Vascular	<i>Solidago caesia</i>	n/a	Edge
		Vascular	<i>Vaccinium cf.</i>	n/a	Cliff
			<i>pallidum</i>		
		Moss	<i>Platygyrium repens</i>	n/a	Edge
		Lichen	<i>Buellia spuria</i>	n/a	Cliff

		Lichen	<i>Lasallia papulosa</i>	n/a	Cliff
		Lichen	<i>Lepraria membranacea</i>	n/a	Edge
		Lichen	<i>Parmelia squarrosa</i>	n/a	Edge
		Lichen	<i>Parmotrema</i>	n/a	Edge
		Lichen	<i>Usnea halei</i>	n/a	Cliff
Transect name	Latitude	Group	Species	Listing	Position
Lewis Hollow T22	36.60529196	Vascular	<i>Amelanchier arborea</i>	n/a	Cliff
	Longitude	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	-83.66656104	Vascular	<i>Dichanthelium depauperatum</i>	n/a	Cliff
		Vascular	<i>Galium aparine</i>	n/a	Talus
		Vascular	<i>Pinus virginiana</i>	n/a	Cliff
		Vascular	<i>Vaccinium fuscatum</i>	n/a	Cliff
		Moss	<i>Leucobryum albidum</i>	n/a	Edge
		Moss	<i>Leucobryum glaucum</i>	n/a	Talus
		Moss	<i>Polytrichum juniperinum</i>	n/a	Cliff
		Lichen	<i>Campylopus cf. tallulensis</i>	n/a	Edge
		Lichen	<i>Dimelaena oreina</i>	n/a	Edge
		Lichen	<i>Lasallia papulosa</i>	n/a	Edge
		Lichen	<i>Lasallia pensylvanica</i>	n/a	Cliff
		Lichen	<i>Lecanora thysanophora</i>	n/a	Cliff
		Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
		Lichen	<i>Pleopsidium flavum</i>	n/a	Cliff
		Lichen	<i>Rhizocarpon disporum</i>	n/a	Edge
Transect name	Latitude	Group	Species	Listing	Position
Lewis Hollow T23	36.60529196	Vascular	<i>Acer rubrum var. rubrum</i>	n/a	Talus
	Longitude	Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	-83.66656104	Vascular	<i>Carex l</i>	n/a	Talus
		Vascular	<i>Galax urceolata</i>	n/a	Talus
		Vascular	<i>Hamamelis virginiana</i>	n/a	Talus
		Vascular	<i>Pinus virginiana</i>	n/a	Cliff
		Vascular	<i>Vaccinium cf. pallidum</i>	n/a	Cliff
		Moss	<i>Ceratodon purpureus</i>	n/a	Cliff
		Moss	<i>Leucobryum albidum</i>	n/a	Edge
		Moss	<i>Leucobryum glaucum</i>	n/a	Edge

Lichen	<i>Chrysothrix</i>	n/a	Cliff
Lichen	<i>Dimelaena oreina</i>	n/a	Edge
Lichen	<i>Lasallia papulosa</i>	n/a	Edge
Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
Lichen	<i>Melanelia culbersonii</i>	n/a	Cliff
Lichen	<i>Paraparmelia alabamensis</i>	n/a	Cliff
Lichen	<i>Rhizocarpon disporum</i>	n/a	Edge
Lichen	<i>Umbilicaria mammulata</i>	n/a	Cliff
Lichen	<i>Usnea halei</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Cumberland Trail T24	36.60558701	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Talus
		Vascular	<i>Betula alleghaniensis</i>	n/a	Cliff
	-83.66926303	Vascular	<i>Pinus virginiana</i>	n/a	Cliff
		Vascular	<i>Sassafras albidum</i>	n/a	Talus
		Vascular	<i>Vaccinium fuscatum</i>	n/a	Edge
		Moss	<i>Campylopus</i> cf. <i>tallulensis</i>	n/a	Cliff
		Moss	<i>Dicranum condensatum</i>	n/a	Talus
		Moss	<i>Leucobryum albidum</i>	n/a	Talus
		Moss	<i>Polytrichum ohioense</i>	n/a	Talus
		Lichen	<i>Dimelaena oreina</i>	n/a	Edge
		Lichen	<i>Kalmia Latifolia</i>	n/a	Cliff
		Lichen	<i>Lasallia papulosa</i>	n/a	Edge
		Lichen	<i>Lasallia pensylvanica</i>	n/a	Edge
		Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
		Lichen	<i>Paraparmelia alabamensis</i>	n/a	Edge
		Lichen	<i>Parmelia squarrosa</i>	n/a	Edge
		Lichen	<i>Parmelinopsis minarum</i>	n/a	Cliff
		Lichen	<i>Physcia aipolia</i>	n/a	Edge
		Lichen	<i>Physciella melanchra</i>	n/a	Cliff
		Lichen	<i>Polysporina simplex</i>	n/a	Cliff
		Lichen	<i>Rhizocarpon disporum</i>	n/a	Edge
		Lichen	<i>Rimelia</i>	n/a	Cliff
		Lichen	<i>Silene rotundifolia</i>	n/a	Cliff
		Lichen	<i>Umbilicaria virginis</i>	n/a	Cliff
		Lichen	<i>Usnea halei</i>	n/a	Cliff

Transect name	Latitude	Group	Species	Listing	Position
Cumberland Trail T25	36.605586	Vascular	<i>Acer rubrum</i> var. <i>rubrum</i>	n/a	Talus
		Vascular	<i>Asplenium montanum</i>	n/a	Cliff
	-83.66926404	Vascular	<i>Betula lenta</i>	n/a	Talus
		Vascular	<i>Silene rotundifolia</i>	n/a	Cliff
		Vascular	<i>Smilax rotundifolia</i>	n/a	Talus
		Vascular	<i>Vaccinium</i> cf. <i>parviflora</i>	n/a	Talus
		Vascular	<i>Vaccinium</i> <i>stamineum</i>	n/a	Cliff
		Moss	<i>Hypnum pallescens</i>	n/a	Cliff
		Moss	<i>Leucobryum albidum</i>	n/a	Talus
		Moss	<i>Leucobryum albidum</i>	n/a	Talus
		Lichen	<i>Imshaugia aleurites</i>	n/a	Cliff
		Lichen	<i>Lecanora oreinoides</i>	n/a	Cliff
		Lichen	<i>Lepraria lobificans</i>	n/a	Cliff
		Lichen	<i>Parmelia squarrosa</i>	n/a	Cliff
		Lichen	<i>Physonica</i>	n/a	Cliff
		Lichen	<i>Rhizocarpon</i> <i>disporum</i>	n/a	Cliff
		Lichen	<i>Umbilicaria virginis</i>	n/a	Cliff
		Lichen	<i>Usnea halei</i>	n/a	Cliff

Appendix E –Enlarged GIS map

