

Importance of a Small, Urban–Suburban National Park to the Conservation of Rare, Threatened, and Endangered Plant Species

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Abstract - The United States National Park Service protects and preserves iconic landscapes and their associated and unique natural and cultural resources across the country. Although many of these national parks, particularly in the eastern US, were established for their historical importance, these small, protected areas can house notable biological diversity. The Chesapeake and Ohio Canal National Historical Park, an historic park within and proximate to the nation's capital, has long been the subject of botanical surveys, in part because of the diverse plant communities it contains. Herein, we synthesized historic botanical data on rare plant species within the park and summarized 14 years of recent data-collection efforts. Of the 191 rare, threatened, and endangered plant species historically documented, we identified 105 species that contain current populations within the park, but we were unable to relocate the remaining 86 species. Based on the State of Maryland species conservation ranks, critically imperiled species were no more likely to be documented during our study than were historically recorded species, potentially indicating that more species have become locally extirpated than previously known. Despite the intensity of local land-use and anthropogenic stressors, urban–suburban protected areas such as the subject national park are critical for the integrity of rare-plant populations. We provide descriptions of the unique plant species, communities, and conservation threats.

Introduction

Established in 1916, the United States National Park Service (NPS) was created as a means to preserve natural resources, maintain scenic views and landscapes, and protect the nation's natural and cultural history. Over 100 years later, the NPS now administers and manages biologically diverse terrestrial and aquatic habitats across the country. To ensure the effective stewardship of biological resources and consistency of management practices across the hundreds of individually administered units of the NPS, the bureau established guiding management policies (NPS 2006). These policies require national parks to protect native plants and animals, minimize negative effects of invasive species, and conserve and restore species of

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conservation concern. Specifically, these management policies require the NPS to inventory, monitor, and manage rare, threatened, and endangered species, whether protected by the Endangered Species Act or State law and regulation (NPS 2006). The unique geology and topography of many national parks, particularly the larger and more mountainous parks, create unique habitats that generate incredible biodiversity (e.g., Carril et al. 2018). In addition to the iconic, montane landscapes, urban and suburban protected areas may similarly protect high-quality habitats and biodiverse plant and animal communities (Adams et al. 2020, Dyderski et al. 2017).

The Chesapeake and Ohio Canal National Historical Park (hereafter, the Park) is a long, narrow administrative unit of the NPS that borders the northern bank of the Potomac River from Washington, DC, to Cumberland, MD (Fig. 1). Established as a national monument in 1961 and provided a management budget and national park designation in 1971, the Park was initially designed to protect the historic canal and associated transportation infrastructure. Consequently, the Park now provides a protected, mostly forested landscape and riparian corridor that follows the canal across a gradient of urban to suburban to rural land uses. Deciduous and mixed deciduous–evergreen forests dominate lands within the Park’s legislative boundary, comprising nearly 70% of the land cover, while less than 6% of the Park consists of developed or open lands per the 2016 National Land Cover Database (Dewitz 2019). While proximate to other forested conservation areas such as Green Ridge State Forest, this protected landscape traverses through agricultural lands and heavily developed areas of Cumberland, Hancock, Williamsport, Potomac, and Cabin John in Maryland, as well as the sprawl of Washington, DC.

The Park’s eastern edge begins inside the nation’s capital, where the slow-moving waters of the Piedmont and Coastal Plain physiographic provinces are

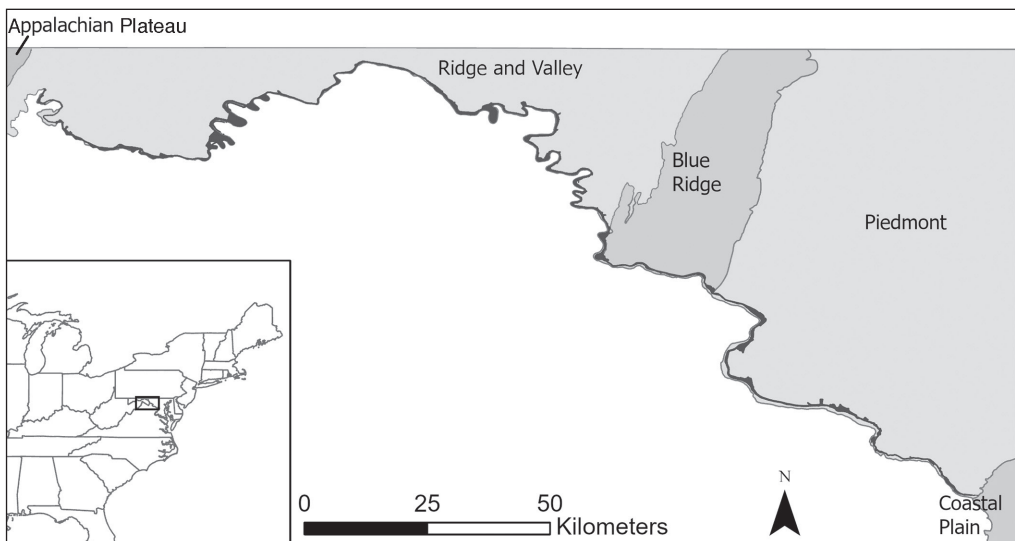


Figure 1. Map of study area showing the Chesapeake and Ohio Canal National Historical Park and physiographic provinces of Maryland. Dark shading along the southern border of Maryland indicates the legislative boundary of the Park.

underlain by metamorphosed quartz and sedimentary sandstones (Southworth et al. 2008). The Fall Line of the Potomac River, separating the sandy soils of the Coastal Plain and the erosion-resistant rocks of the Piedmont province, creates unique plant communities including ancient bedrock terraces and flood-scoured islands in an area known as the Potomac Gorge (Southworth et al. 2008). This area of the Piedmont is characterized by drastic reductions in elevation along the Potomac River and is underlain by metamorphosed sedimentary and intrusive igneous rock formations (Brown and Brown 1984). Northward, the Park enters the Blue Ridge physiographic province, which is characterized by metamorphosed sandstones and shales as well as ancient Precambrian schists and gneisses that form the Blue Ridge Mountain range (Southworth et al. 2008). Further upriver, the Park enters the Great Hagerstown Valley, a component of the Ridge and Valley physiographic province, which features rich calcareous valleys and striking limestone outcroppings (Southworth et al. 2008). Situated to the west are the numerous folds and faults of the Ridge and Valley physiographic province that include a variety of sedimentary rock formations (Shreve et al. 1910, Southworth et al. 2008). The unequal weathering rates of these rocks over time have produced a unique array of sandstone cliffs and outcroppings, limestone bedrock exposures, and steep, shale scree slopes. The Ridge and Valley ends near the Park's terminus in Cumberland, MD. Owing in part to this geologic and physiographic diversity, the Park contains a breadth of unique habitats and ecosystems, which begets an extraordinary diversity of plant communities and species, as discussed herein.

Given the proximity to the nation's capital and other urban centers, habitats within the Park have been extensively sampled for well over a century, with the oldest recorded occurrence of a plant species of conservation concern dating back to an 1870 collection of *Valerianella umbilicata* (Navel Cornsalad; *Chickering 1416639* US). Areas adjacent to Washington, DC, were particularly popular research sites for many botanists and natural history scientists prior to the formal establishment of the Park. As a result, many early collections are currently curated at the Smithsonian National Museum of Natural History (US). Conversely, the proximity of the Park to urban areas and suburban development has also caused conservation issues and resource threats related to anthropogenic land use. Notably, prevalent pressures from both invasive species (Miller et al. 2020) and dense populations of *Odocoileus virginianus* (Zimmermann) (White-tailed Deer; Knapp and Wiegand 2014) in the Park and across similar urban-suburban landscapes affect the survival and longevity of native plant species.

Through this work, we herein summarize the rare, threatened, and endangered plant species historically documented and recently identified throughout the Park. Our objectives through this work were to (1) synthesize various written reports, historical records, unpublished data, and dynamic databases describing the presence and location of plant species of conservation concern within the Park, (2) summarize historical and recently collected data on rare, threatened, and endangered plant species within the Park, and (3) identify patterns of species persistence over time. These results will both inform conservation and protection efforts and help drive future monitoring and research.

Methods

We synthesized historical data between 1870 and 2007 from various sources, including agency-commissioned reports, museum herbaria specimens, visitor reports, and scientific literature reviews. Works funded, authorized, or carried out by the NPS included Boone (1986), Wiegand and Becker (1995), Wiegand (1999; 2001a, b), and Lea and Frye (2002). We gathered additional data from efforts directed by the NPS, generally to inform the agency of whether any potential development or facility-maintenance undertaking may affect significant plant species. As such, these surveys were site-specific and resulted in a checklist of species of conservation concern within the boundaries of the proposed project. We also reviewed other works, completed either prior to federal ownership of the lands or by author(s) not affiliated with the NPS, for relevant occurrences of targeted plant species. These studies included documents by Shreve et al. (1910), Terrell (1970), Riefner and Hill (1983), and Shetler et al. (2006). We also compiled data from local herbaria, including the Maryland Department of Natural Resources Tawes Herbarium (TAWES) and US; resolved taxonomic inconsistencies to ensure we accounted for changes in species designations over time; and confirmed species attributions with published distributional data, including but not limited to Knapp and Naczi (2021) and Weakley et al. (2022). Taxonomy, common names, and listed authorities follow Weakley et al. (2022) with authority abbreviations following ITIS (2023). Herbarium abbreviations follow Index Herbariorum (Thiers 2023).

We used these historical reports and documentation to identify and prioritize specific plant communities, geographic locations, and target populations for active data-collection efforts. Using the prior documentation and natural history information about the target species, we relocated extant occurrences and opportunistically searched for individual plants in all proximate, suitable microhabitats. We actively surveyed sites for the presence of the rare, threatened, and endangered plant species occurrences from 2008 through 2021, with some level of survey effort completed in all years except 2011, 2012, and 2014. These data-collection efforts were led by the NPS and often included youth botanist internships, fellowships, and students. Species identifications between 2008 and 2021 were confirmed by NPS or Maryland State botanists. We referenced museum specimens for species confirmation, including specimens from TAWES, US, the Norton–Brown Herbarium at the University of Maryland, College Park (MARY), the United States National Herbarium (NA), and the C.V. Starr Virtual Herbarium, an online repository of digitized specimens from the William and Lynda Steere Herbarium at the New York Botanical Garden (NYBG).

We identified specific areas of the Park that lacked documentation of existing plant species of conservation concern to ensure the paucity of data represented absence of the species and not lack of survey effort. For high-priority species, including those designated as endangered either in Maryland or for the entire US (e.g., *Harperella nodosa* [Harperella]), known to be exploited (e.g., *Panax quinquefolius* [American Ginseng]), or experiencing steep, regional declines (e.g., *Ripariosida hermaphrodita* [Virginia-mallow]) (Weakley et al. 2022), we identified

habitat requirements and commonly associated species in order to locate potential habitats likely to support the species. We then conducted targeted, opportunistic searches of proximate habitats to ensure we recorded the parameters of the occurrence. Similarly, for species without historic documentation, we conducted targeted surveys in specific microhabitats wherein the species would likely exist. We considered plant species occurrences as spatially distinct when there existed at least 1 km between occurrences (NatureServe 2002). If individuals of the plant species were noted within 1 km, we included these as a single occurrence.

We recorded all data on handheld GPS equipment (Trimble Ranger, GeoXH, or Juno SB; Westminster, CO) or on similar devices with enabled georeferencing capacity (Apple iPad Mini Air; Cupertino, CA), with 2- to 5-m spatial resolution. We then compiled data within an ArcGIS Online system (Esri, Redlands, CA). We categorized all observations into distinct, broadly described plant communities following Harrison (2016). For known rare plant occurrences, we confirmed populations in the field to ensure identified community associations accurately characterized the habitat. We identified plant species of conservation concern using the conservation status rank assigned by Frye (2021) and NatureServe (2021). Conservation status ranks are intended to indicate risk of elimination or extinction in the foreseeable future and are arranged along a simple numerical scale (1–5), with the lower numbers reflecting increasing rarity and risk. Conservation ranks also present geographic information about rarity. Subnational (state) ranks (S ranks) communicate the rarity of the species in the state, whereas global ranks (G ranks) communicate the rarity of the species throughout its range. The rank of a species is determined through analyses of population number, size, viability, threats, and trends, among other criteria (NatureServe 2020). The final metric, a combination of the numeric index (1–5) and the geographic identifier (G or S), distills this large amount of information into a single metric. Thus, for a particular plant species that has a global rank of G1 and a state rank of S1, the species is not only rare and at risk of elimination within Maryland but also rare throughout its entire range and at risk of extinction. Species ranks of SH and SX indicate historical occurrences and species that are considered extirpated from the state, respectively.

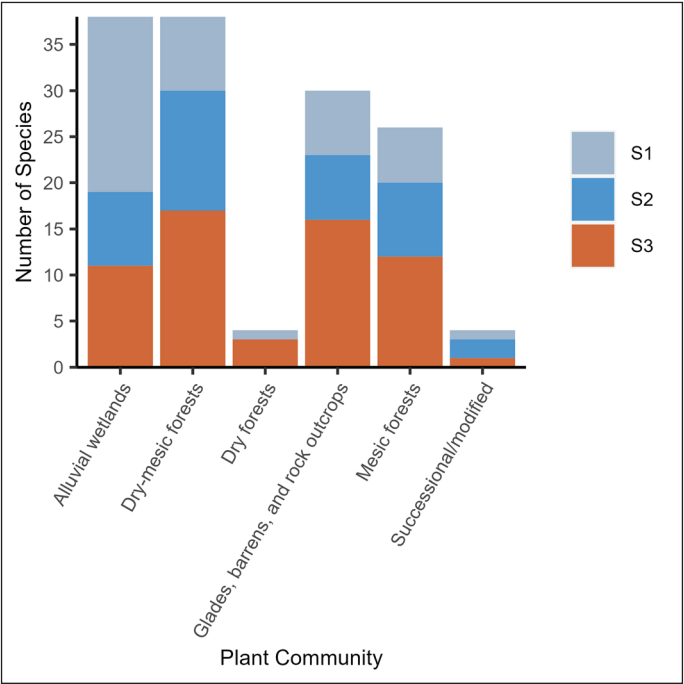
Within Program R 4.2.3 (R Core Team 2023), we used a generalized linear model with negative binomial distribution in package ‘MASS’ (Venables and Ripley 2002) to examine the relationship between number of growing seasons since last observation of a plant species and the state conservation ranking. We also employed a binomial logistic regression model to examine whether species we successfully located during our sampling period were correlated with the state conservation ranking. For analyses, we placed species ranked between 2 categories (e.g., S1S2) in the more imperiled ranking and included historic and extirpated in the same category.

Results

Between 2008 and 2021, we recorded 105 rare, threatened, and endangered plant species (Appendix 1). Species were noted in 1278 spatially distinct

occurrences, documented across ~291 km spanning the various physiographic provinces within our study area (Fig. 1). Grouped by plant community descriptions, species were documented in 6 distinct plant communities (Fig. 2). Of the species we documented, 37 were considered critically imperiled (S1) and 29 were considered imperiled (S2) in Maryland (Maryland Natural Heritage Program 2021). In terms of conservation importance across their entire distribution, 12 species within the Park were considered globally imperiled (G2) or vulnerable (G3). Only 1 species, *Harperella*, was listed as endangered under Federal law (as *Ptilimnium nodosum*). Despite intensive resurvey efforts, we were unable to relocate 86 plant species that had previously been identified within the Park (Appendix 2). Of the rare species not observed, 41 were identified as critically imperiled in the state and 7 species were noted as historic occurrences in Maryland. Additionally, 5 species were considered globally vulnerable, 2 as globally imperiled, and 1 species, *Pycnanthemum clinopodioides* (Basil Mountain-mint), was noted as G1G2. Four species not seen during our sampling have since been considered extirpated from Maryland: *Arnoglossum reniforme* (Great Indian-plantain), *Carex tenera* (Quill sedge), *Trifolium reflexum* (Buffalo Clover), and Navel Corns salad. All species we observed and documented were previously known from Maryland except for *Valerianella chenopodiifolia* (Goosefoot Corns salad), which was excluded from the recent state flora in Knapp and Naczi (2021); however, we observed the species within the Park and confirmed identification of a voucher specimen from just outside of the Park boundary in Maryland (*Boone s.n.* TAWES). Surveyed species of concern, descriptions of associated plant species, and conservation threats are herein separated by plant community.

Figure 2. Number of species and state conservation ranks documented between 2008 and 2021 in various plant communities within the Chesapeake and Ohio Canal National Historical Park. State rank codes follow Maryland Natural Heritage Program (2021) and represent critically imperiled (S1), imperiled (S2), and watchlist (S3) species.

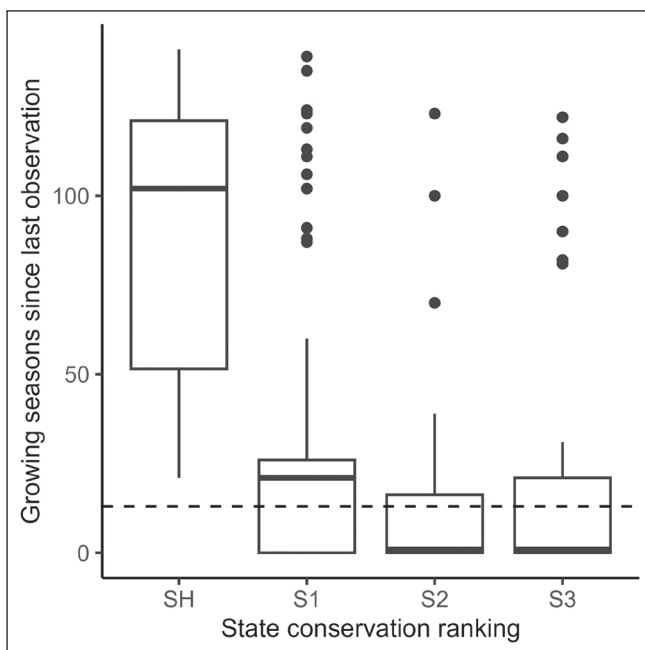


Conservation ranks of targeted plant species were significantly correlated with the number of growing seasons between the current year and the date of last observation ($F_{3,187} = 4.826$; $P = 0.0029$). In comparison to extirpated or historically documented species, both imperiled S2 ($z = -2.381$; $P = 0.0173$) and watchlist S3 ($z = -2.094$; $P = 0.0363$) ranked plants were observed significantly more recently (Fig. 3). Imperiled S2 species ($z = -2.077$; $P = 0.0378$) were also more likely to be observed within recent history when compared to critically imperiled S1 species. Similarly, State conservation ranks of targeted plant species were significant in predicting whether we were able to successfully relocate plant species ($F_{3,187} = 6.033$; $P = 0.0006$). Specifically, both S2 ($z = 2.253$; $P = 0.0242$) and S3 ($z = 1.811$; $P = 0.0702$) species were more likely than S1 species to have been documented during the sampling period, albeit only marginally more likely for S3 species. We relocated between 68% and 62% of S2 and S3 species, respectively, while we only relocated 47% of S1 species (Fig. 3). The likelihood of documenting critically imperiled S1 species did not significantly differ from species considered historic or extirpated from Maryland ($z = -0.018$; $P = 0.9855$).

Mesic forests

Mesic forests comprised the most common terrestrial class found throughout the Park and in each physiographic province, and they included a diversity of rare plant species. Lying in the floodplain of the Potomac River, the nutrient-rich soils of these forests supported tall, large-diameter trees such as *Platanus occidentalis* L. var. *occidentalis* (Sycamore), *Acer saccharinum* L. (Silver Maple), *Liriodendron tulipifera* L. var. *tulipifera* (Tulip-tree), *Quercus shumardii* (Shumard Oak), and *Populus deltoides* ssp. *deltoides* W. Bartram ex Marshall (Eastern Cottonwood),

Figure 3. Number of growing seasons from date of last observation of targeted plant species with state conservation ranks of historic/extirpated (SH), critically imperiled (S1), imperiled (S2), and watchlist (S3) plant species across study area. Dashed line and below represents sampling period between 2008 and 2021. State rank codes follow Maryland Natural Heritage Program (2021).



which created a closed canopy and provided shade for a well-developed understory. Spring ephemeral species such as *Phacelia covillei* (Eastern Buttercup Phacelia) and *Erigenia bulbosa* (Harbinger-of-spring) grew robustly on the upper flat terraces of the floodplain mesic forests before the canopy closed in the summer. *Asimina triloba* (L.) Dunal (Common Pawpaw) and *Lindera benzoin* (L.) Blume (Northern Spicebush) were characteristic species of the dense mid-story strata in these forests. Calcareous outcroppings and higher soil pH provided habitat for calciphile species such as *Ruellia strepens* (Limestone Wild-petunia) and *Symphyotrichum shortii* (Short's Aster) in regions of the Blue Ridge and Ridge and Valley provinces.

Due to the quality of the soil, flat terrain, and proximity to the Potomac River, these forests have experienced historic and recent development, resulting in a mosaic of forest fragments. More recent development of recreational infrastructure and associated informal trails to the river have also further fragmented mesic forests. Additionally, scattered agricultural fields that persisted along the river exacerbated the spread of invasive species such as *Elaeagnus umbellata* Thunb. (Autumn-olive) and *Perilla frutescens* (L.) Britton (Beefsteak-plant), which frequently encroached into adjacent habitats. Shade-tolerant invasive plant species have become prevalent with significant canopy gaps caused by the recent forest pest *Agilus planipennis* Fairmaire (Emerald Ash Borer), further promoting invasion of several exotic species.

Dry-mesic forests and woodlands

Dry-mesic forests and woodlands were supported by a variety of geological substrates associated with rich and calcareous soils to dry and sandy soils. This geographically widespread class was found between the mesic forests aligning the Potomac River and the drier, upland forests. Overlaps in canopy and understory composition occurred in this class, with both mesic- and dry-forest species present. Lower elevations of this class may be subjected to infrequent flooding events.

Forests on scoured bedrock terrace occasionally experienced disturbance from river flooding, with an approximately 1–10-year cycle. These habitats contained erosion-resistant bedrock outcrops and boulders, as well as flood channels and ravines lined by rock walls. Small pools and potholes filled with surface water were scattered across the visible bedrock. Slightly stunted canopy trees, including *Carya glabra* (Mill.) Sweet (Pignut Hickory), *Quercus rubra* L. var. *rubra* (Northern Red Oak), Shumard Oak, and *Ostrya virginiana* (Mill.) K. Koch (American Hop-hornbeam), formed semi-open woodlands that featured diverse and well-developed understory communities dominated by graminoids and late-season species of the Asteraceae. This endemic plant community is unique to the Potomac Gorge and contained a greater number of imperiled plant species.

Dry-mesic calcareous forests occurred on slopes above the Potomac River within the Blue Ridge and Ridge and Valley provinces, providing basic calcareous and mafic soils that supported diverse plant species. Rich substrates included dry, well-drained soils to moist, well-developed soils. The herbaceous understory community followed this soil-moisture gradient, with flowering ephemeral species

most diverse in the moist soils. Closed, overstory canopies were dominated by *Tilia americana* L. var. *americana* (Northern Basswood), *Acer saccharum* Marsh. var. *saccharum* (Sugar Maple), *Quercus muehlenbergii* Engelm. (Chinquapin Oak), *Q. alba* L. (White Oak), and Tulip-tree. Where a mid-story occurred, common species included *Cercis canadensis* L. var. *canadensis* (Eastern Redbud), *Dirca palustris* (Leatherwood), and *Benthamidia florida* (= *Cornus florida*) (L.) Spach (Flowering Dogwood).

Like other plant communities that depend on river disturbance, global climate change poses a significant threat to these species by altering flood frequency and intensity. Overabundant ungulate populations in regions of the Park can reduce plant diversity and the abundance of woody and herbaceous species (Horsley et al. 2003, Knight 2003). Browsing pressure can also exacerbate the distribution and persistence of common invasive plant species such as *Microstegium vimineum* (Trin.) A. Camus (Japanese Stilt-grass) and *Berberis thunbergii* DC. (Japanese Barberry) (Shen et al. 2016).

Dry forests and woodlands

Dry forests and woodlands were common in the Ridge and Valley province in the western reaches of the Park, occurring on any aspect and on slopes varying from steep to gentle. Substrates were formed from weathered shale or other sedimentary rocks. A moderate tree canopy was primarily composed of *Quercus montana* Willd. (Rock Chestnut Oak), White Oak, and Pignut Hickory. Within the Park, dry forests that supported rare plant species frequently occurred adjacent to shale barrens, comprising woodland complexes outside of the barrens themselves. Given the narrow configuration of the Park and the extent of anthropogenic development outside of the Park boundaries, these forests were restricted in size. Invasive exotic species, including Japanese Stiltgrass, *Rubus phoenicolasius* Maxim. (Wineberry), *Ailanthus altissima* (Mill.) Swingle (Tree-of-heaven), and *Rosa multiflora* Thunb. ex Murray (Multiflora Rose) frequently competed with and threatened native species in dry forests and woodlands.

Glades, barrens, and rock outcrops

This terrestrial plant class was comprised of various plant communities that supported heliophytic and resilient species exposed to extreme climatic conditions and stressors. This terrestrial plant class included many distinct habitat types, including basic and acidic cliffs, barrens, and riverside outcrops. Although the harsh environmental conditions precluded the growth of many plants, certain exotic species, including *Euonymus fortunei* (Turcz.) Hand.-Mazz. (Wintercreeper) and *Hedera* sp. (ivy) vines on limestone cliffs and the forbs *Centaurea stoebe* ssp. *micranthos* (S.G. Gmel. ex Gugler) Hayek (Spotted Knapweed) and *Verbascum thapsus* ssp. *thapsus* L. (Common Mullein) in shale barrens, have begun to invade these habitats. These exotic species are capable of outcompeting native species in these resource-limited habitats. Forest succession, fire suppression, and mesophication all threaten shale barrens and limestone cliffs, with additional pressures from the forest pest *Lymantria dispar* L. (Spongy Moth or Gypsy Moth), a significant defoliator impacting

Quercus spp. (oaks) and other hardwoods (Tyndall 2015). Changes in river hydrology and flood cycles constitute the most significant stressors to species occurring on rock outcrops.

Erosive forces of the Potomac River, in addition to practices employed during the construction of the historic canal, established steep cliffs in areas of the limestone-rich Ridge and Valley and Blue Ridge provinces. Although small in size, these habitats supported a diversity of plant species: Some critically imperiled calciphilic species, including *Pellaea glabella* ssp. *glabella* (Smooth Cliff-brake), *Arabis patens* (Spreading Rockcress), and *Thuja occidentalis* (Northern White Cedar), were restricted to these cliffs and proximate dry forests. Species composition and richness was dependent upon aspect and surface-soil availability. Moist, cool cliffs facing north to northwest supported more overstory and mid-story trees including Sugar Maple, Northern White Cedar, *Juniperus virginiana* L. (Eastern Red Cedar), Leatherwood, and Eastern Redbud. On west- to south-facing slopes, however, thin soils and greater solar irradiance created a more xeric habitat that supported unique assemblages of drought-tolerant species including *Rhus aromatica* Aiton var. *aromatica* (Fragrant Sumac) and American Hophornbeam.

Shale barrens are endemic to the central Appalachian Mountains and typically occur on steep slopes with a south-facing aspect. Soils were dry, nutrient poor, and shallow to non-existent with the substrate generally comprised of erosive shale fragments. Owing to the edaphic pressures faced therein, vegetation in shale barrens was generally sparse, which allowed for a high level of solar irradiance and resultant extreme ground-surface temperatures (Keener 1983). Canopies were incomplete and composed primarily of stunted Eastern Red Cedar, *Pinus virginiana* Mill. (Virginia Pine), *Quercus prinoides* Willd. (Dwarf Chinquapin Oak), and Pignut Hickory. Sparse shrub layers contained *Quercus ilicifolia* Wangenh. (Bear Oak), Fragrant Sumac, and *Rosa* spp. (roses) while *Carex pensylvanica* Lam. (Pennsylvania Sedge), *Danthonia spicata* (L.) P. Beauv. ex Roem. & Schult. (Poverty Oat-grass), and *Dichanthelium linearifolium* (Scribn.) Gould (Low White-haired Witchgrass) were common understory herbaceous species. Shale barren habitats within the Park also supported several endemic heliophytic species, including *Oenothera argillicola* (Shale-barren Evening-primrose), *Trifolium virginicum* (Kate's Mountain Clover), and *Convolvulus spithameus* (Low Bindweed). In Maryland, these plant communities were found only within the western Ridge and Valley province.

Erosion-resistant bedrock surfaces within the corridor of the Potomac River Gorge experienced frequent and intense disturbance from flooding and higher water levels. Exposed rock cliffs, bluffs, and low-lying rocky channels, interspersed with scant vegetation, characterized this landscape. Plants that root in shallow alluvial silts and sands caught in crevices between rocks must be sufficiently resilient to withstand a gradient of environmental conditions from complete inundation to exposed, hot, and dry conditions. These extreme conditions beget the specialized plant species found therein. Although vegetation was often minimal, commonly detected species included *Schizachyrium scoparium* (Michx.) Nash var. *scoparium* (Common Little Bluestem) and *Dichanthelium acuminatum* (Sw.) Gould & C.A.

Clark var. *acuminatum* (Woolly Witchgrass), stunted *Hypericum prolificum* L. (Shrubby St. John's-wort), late season herbs such as *Ionactis linariifolia* (L.) Greene (Stiff-leaved Aster), and a variety of foliose and crustose lichens.

Alluvial wetlands

Plant communities within the alluvial wetland class included those variously affected by the Potomac River, with communities defined by the intensity and periodicity of flooding events. The stochasticity of these environments supported many rare plant species throughout the Park. In addition to invasive species such as *Lespedeza cuneata* (Dum. Cours.) G. Don (Chinese Lespedeza) and ornamental plants escaped from suburban neighborhoods, changes to river hydrology and flood frequency caused by global climate change constitute a significant threat to species within the alluvial wetland class.

Waters from annual flooding deposited sand, gravel, and cobble in shallow, flat areas of the river margins, ultimately creating a variety of habitats including permanent depositional bars and unstable, transitory habitats. Plant populations must adapt to this stochasticity, as changing river conditions can quickly modify the availability of suitable habitat in any given year. Dynamic depositional bar habitats commonly supported stands of *Justicia americana* (L.) Vahl (American Waterwillow) and other late-flowering ephemeral herbaceous species. Depositional bars in slower or more protected waters also supported *Hibiscus laevis* (Smooth Rose-mallow) and often featured stunted floodplain forest trees such as Sycamore and *Betula nigra* L. (River Birch). Species supported by such habitats, including the endangered Harperella, are particularly sensitive to changes in river hydrology.

Scoured riverside prairie habitats are also maintained by frequent and intense flooding, albeit less frequently on an approximate 1–5-year cycle. Bedrock ledges and shelves, formed and shaped by floodwaters, can become inundated during the winter and spring and can vary from well-drained to xeric in the summer and fall. Between rocks and boulders, alluvial depositions from the river built and provided substrate for vegetation. Because of the frequent flooding and shallow sandy soils, woody vegetation was sparse and stunted where able to persist. Herbaceous plants and grasses dominated this habitat type; however, they were dependent upon the stochastic conditions brought about by regular riverine flooding. Some plant species that can be found in riverside prairies, including *Helianthus occidentalis* ssp. *occidentalis* (Naked-stem Sunflower) and *Eleocharis compressa* var. *compressa* (Flattened Spikerush), comprised populations disjunct from the rest of their range in the midwestern US. Within the Park, these habitats were found only within the Potomac Gorge, near the Fall Line between the Piedmont and Atlantic Coastal Plain physiographic provinces. Riverside prairies transitioned to river-scour woodlands with even less-frequent flooding disturbance. These open forests were dominated by *Carya cordiformis* (Wangenh.) K. Koch (Bitternut Hickory) and various *Quercus* spp., including Northern Red Oak, Shumard Oak, and *Q. macrocarpa* Michx. var. *macrocarpa* (Bur Oak), with tall, late-season herbs and graminoids forming a dense understory.

Successional/modified vegetation

The construction and subsequent abandonment of the historic canal within the Park incidentally established a series of artificial wetlands, constituting varying sizes and hydroperiods. Although not specifically included within the classification framework by Harrison (2016), these artificial wetlands, certainly established by human landscape modification, provided habitat for several rare plant species. Invasive plant species such as *Myriophyllum aquaticum* (Vell.) Verdc. (Parrot-feather) and *Iris pseudacorus* L. (Yellow Flag) grew in dense mats and consumed oxygen after senescence, ultimately affecting the integrity of these habitats. Additionally, cultivated hay fields in the Ridge and Valley province contained the largest Maryland population of *Pycnanthemum virginianum* (Virginia Mountain-mint), which has benefited from regular mowing disturbance.

Discussion

Beyond the historic importance for which it is more widely recognized, the Park also provides habitat for a significant number of plant species of conservation concern in Maryland and the broader geographic region. Of all 191 rare, threatened, and endangered plant species reported within the Park's jurisdictional boundaries over the past century and a half, our results show that at least 105 species are still supported by habitats within the Park. For some species, the last remaining population in the state is contained within the Park; as such, the Park significantly contributes to the Maryland flora. Both *Trillium nivale* (Snow Trillium; Fig. 4A) and *Ribes americanum* (American Black Currant), each known only from a single occurrence across Maryland, persist within the Park. The Park population of Snow Trillium, an early-blooming calciphile, consists of hundreds to thousands of individuals located in a high-quality limestone oak-hickory forest. A small population of American Black Currant, previously known only from a museum specimen in Maryland (Norton s.n. MARY), was discovered during the sampling period in a mid-successional floodplain forest (Minney and Landsman 2018). Similarly, the Park supports other species which comprise disjunct populations restricted to unique plant communities within the Potomac Gorge. Several species are locally abundant within this area of the Park but are not known to exist elsewhere in Maryland. Examples of these species include *Solidago racemosa* (Sticky Goldenrod), Naked-stem Sunflower, *Coreopsis tripteris* (Tall Coreopsis), and *Amelanchier nantucketensis* (Nantucket Serviceberry).

Data-collection efforts during our sampling period have also led to revisions of the plant species list that affords state legal protection. *Paspalum fluitans* (Water Paspalum), upon intensive surveying efforts of suitable habitats within the Park, was moved from state listed as endangered to threatened. With additional targeted sampling of suitable habitat and extant populations, Eastern Buttercup Phacelia (Fig. 4B) was also recently downlisted from endangered to threatened in Maryland. Similarly, data gathered through this work will contribute to state efforts for enhanced species protections (i.e., uplisting) as those taxa are reviewed. Populations of other species more significantly contribute to broader, regional plant

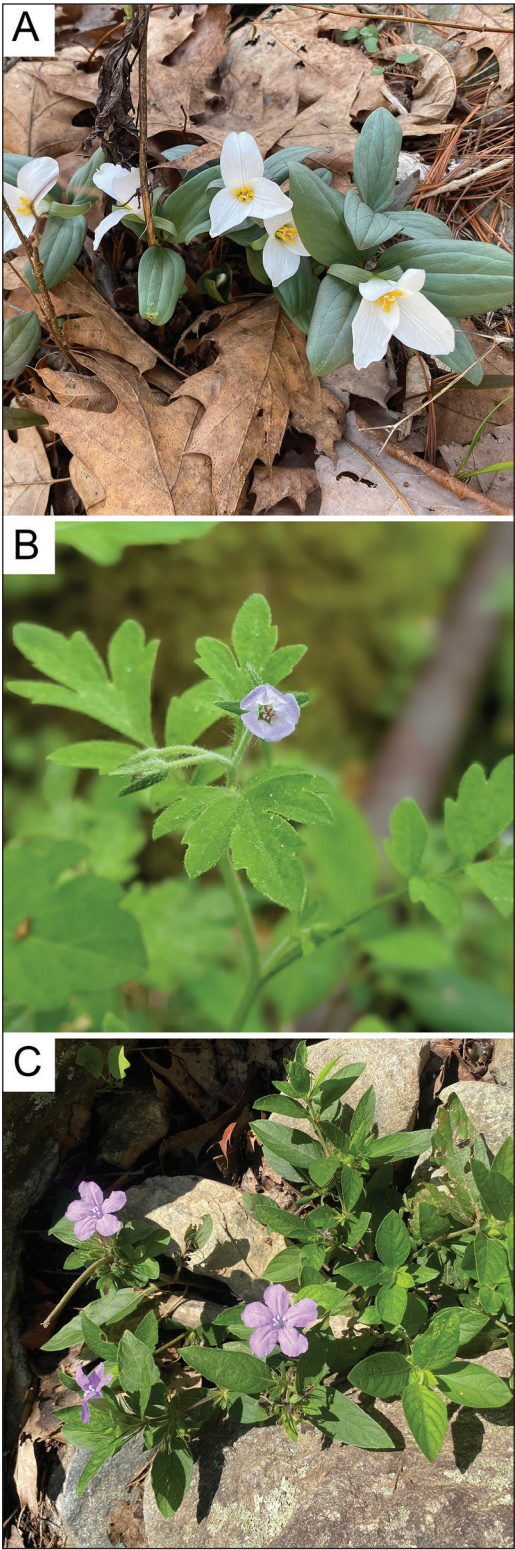


Figure 4. Representative images of (A) *Trillium nivale* (Snow Trillium), (B) *Phacelia covillei* (Eastern Buttercup Phacelia), and (C) *Ruellia humilis* (Hairy Wild-petunia). Photographs taken by L. Strickler and C.R. Thiel.

conservation across the eastern US and in the global distribution of certain species. For example, Park populations contributed to the regional persistence of *Paronychia virginica* (Virginia Whitlow-wort), *Campanula rotundifolia* (Harebell), and *Ruellia humilis* (Hairy Wild-petunia; Fig. 4C). Additionally, plant communities such as Potomac River bedrock terraces (Fig. 5A) and central Appalachian shale barrens (Fig. 5B) supported populations of globally rare and range-restricted plants, including *Scutellaria saxatilis* (Rock Skullcap), Kate's Mountain Clover, and Shale-barren Evening-primrose.

Despite the diversity of individual plant species of conservation concern that we documented, we were unable to relocate historical populations of 86 species in the Park, ~45% of the total known rare flora. At many, if not most, of the locations of these previously documented or reported occurrences, recent survey efforts noted the expansion of invasive exotic vegetation. Common invasive plant species including *Alliaria petiolata* (M. Bieb.) Cavara & Grande (Garlic Mustard), Japanese Stilt-grass, *Reynoutria japonica* Houtt. var. *japonica* (Japanese Knotweed), and *Ficaria verna* Huds. (Fig Buttercup) have become established and threaten the integrity of mesic floodplain forests throughout the study area. *Lespedeza cuneata*, *Datura stramonium* L. (Jimsonweed), and *Humulus scandens* (Lour.) Merr. (Japanese Hops) have displaced sensitive species in areas of dynamic river scour, and climbing vines such as *Hedera* sp. and Wintercreeper have invaded limestone cliff habitats.

Beyond competing invasive plant species, other threats to long-term plant population stability include habitat loss, human-caused physical disturbance, and climate change, all of which are evident throughout the Park and have affected the integrity of many threatened and endangered plant species. Anthropogenic land use and infrastructure development reduces contiguous available habitat for sensitive species, facilitates the spread of invasive and exotic plant species (Mortensen et al.

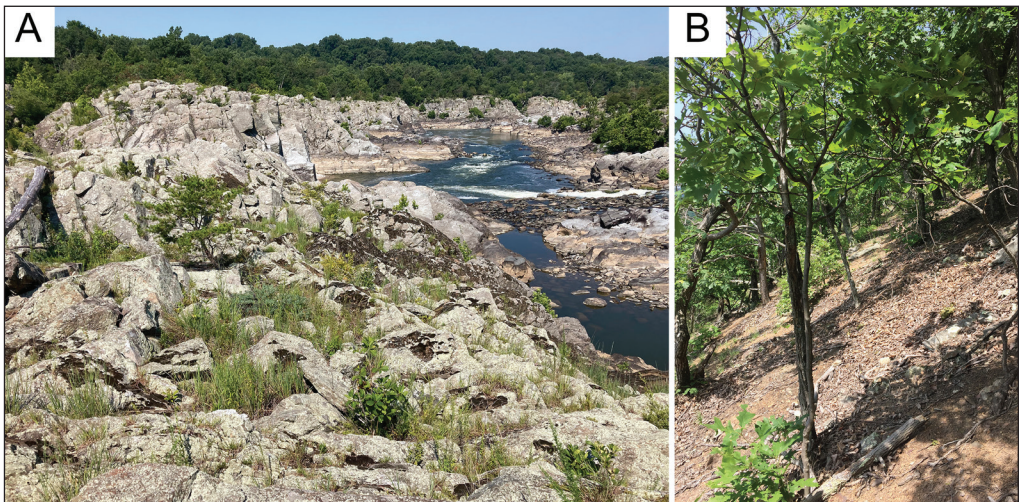


Figure 5. Representative images showing (A) riverside rock outcrops and (B) central Appalachian shale barrens. Photographs taken by V.J. Svahnström and A.P. Landsman.

2009), and results in an increase of deposited alluvium in downstream habitats, all of which can affect threatened and endangered plant species in the Park, particularly in habitats closer to Washington, DC. During our sampling period, we found 58 rare, threatened, and endangered species located within the Potomac Gorge, which lies within a heavily urbanized region. In contrast to the mostly forested Park, surrounding areas consisted of nearly 2 times more developed lands than forest: ~64% of land cover within 2 km of the Park is designated as developed in the 2016 National Land Cover Database (Dewitz 2019). Related to adjacent land development, visitation to the Park nearly doubled during the sampling period, reaching 5 million annual visitors in recent years (NPS 2021).

While less conspicuous than invasive plants and other stressors, changes in global climate have the capacity to drastically affect sensitive plant species (Loarie et al. 2008). Rare species often exhibit low genetic diversity and small population sizes, and thus are more sensitive to shifts in climate (Ellstrand and Elam 1993, Körner et al. 2010). Species in disparate, insular habitats and those that depend on periodic river scour and disturbances may be disproportionately affected by changes in local climate and river hydrology, ultimately affecting the continued persistence of these rare species in the Park (Cartwright 2019, Reed et al. 2021).

Although we did not find 86 previously documented species during our sampling period, we may have unintentionally missed species that do still exist within the Park. Rare species with low population densities (e.g., *Carex careyana* [Carey's Sedge]) may be overlooked despite targeted searches (Lea and Frye 2002). Other species may experience drastic temporal shifts in flowering population size (e.g., Eastern Buttercup *Phacelia*) or may persist in the seed bank until environmental conditions improve (e.g., *Triphora trianthophoros* var. *trianthophoros* [Three Birds Orchid]), leading to logistical issues in consistently detecting species (Kéry and Gregg 2004, Knapp and Wiegand 2014). Still others may be more easily overlooked, depending on vegetative state (Kéry and Gregg 2003). We were more likely to document imperiled and watchlist species during our sampling period than critically imperiled species. These critically imperiled species may consist of smaller, disjunct populations that may be more difficult to detect, or this may indicate local extirpation and decline in the prevalence of the species. However, our success relocating critically imperiled species was not significantly different than our ability to locate historic or extirpated species, indicating that more critically imperiled plant species may be locally extinct within the Park.

Given the expansive anthropogenic development throughout the mid-Atlantic US, protected conservation areas therein remain critical for the long-term survival of sensitive species (Gallardo et al. 2017). These protected areas, particularly when configured and oriented to facilitate species movement and dispersal to other protected lands, help buffer the negative effects of development and habitat loss to rare species. Throughout its length, the Park abuts numerous state-managed conservation lands, as well as other NPS units and county and local protected lands. While managed independently by the various agencies, effective biodiversity conservation must extend beyond administrative boundaries to focus on

a landscape-level approach to management (Leslie 2014). Several plant species of conservation concern for which we had surveyed, including *Blephilia ciliata* (L.) Benth. (Downy Woodmint), *Chenopodium standleyanum* Aellen (Woodland Goosefoot), *Delphinium exaltatum* Aiton (Tall Larkspur), *Platanthera peramoena* (A. Gray) A. Gray (Purple Fringeless Orchid), *Polygala senega* var. *senega* (Northern Senega Snakeroot), *Galium latifolium* Michx. (Purple Bedstraw), *Cubelium concolor* (Eastern Green-violet), *Senna marilandica* (Maryland Wild Senna), and *Taenidia montana* (Mack.) Cronquist (Mountain Pimpernel) were not located within the Park; however, we did locate populations in protected areas adjacent to the Park. Although not documented within the Park, these occurrences exemplify the importance of cross-boundary cooperation for effective conservation.

The detailed information on rare plant populations and locations that we have compiled is critical for the long-term management and successful conservation of these species both locally and across their broader distribution. In situ protection efforts, such as removal of invasive species and fencing to protect from herbivory, can lessen impacts on threatened or sensitive species. Ex situ propagation from collected seed could help augment population densities, facilitate gene flow, enhance genetic diversity, and provide critical information related to germination requirements; Park staff are currently undertaking such efforts to augment extant populations. Through this work, we noted the local loss of many critically imperiled S1 plant species. With the current data serving as an updated baseline inventory, we are now able to assess drivers of plant decline and begin both active management of extant populations and reintroduction of extirpated species and populations into suitable habitats. Given the low population densities for many species and the robust housing and stewardship policies for NPS museum collections that we were unable to meet, we did not collect voucher specimens. As populations respond to active management, the Park should work toward establishing voucher specimens of these rare species to aid future work to revisit and revise taxonomy and species attributions, as necessary. Although we were unable to relocate dozens of target species, the Park continues to provide habitat for over 100 rare, threatened, and endangered plant species. Stressors on the protected habitats within the Park are similarly prevalent in urban–suburban areas throughout the eastern US, likely causing similar threats to other parks and conservation areas (Beissinger et al. 2016). As such, the continued conservation of Maryland's rare plant species and suitable habitats requires a multifaceted approach, leveraging the interconnected nature of local, state, and federal conservation lands across the state.

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Appendix 1. Plant species of conservation concern that were observed in the Chesapeake and Ohio Canal National Historical Park between 2008 and 2021, including the broad plant community wherein species were detected. State and global rank codes follow NatureServe (2021) and Maryland Natural Heritage Program (2021). State and global designations follow the conservation status rank assigned by Maryland Natural Heritage Program (2021) and NatureServe (2021). The rank qualifier “T” indicates that an infraspecific subspecies or variety is ranked differently than the species and the rank qualifier “?” indicates uncertainty that may span multiple ranks. Plant communities/habitats: M= mesic forests, D–M = dry–mesic forests, D = dry forests, G = glades, barrens, and rock outcrops, A = alluvial wetlands, and S = successional/modified.

Plant family	Species name	State and global rank	Plant communities/habitats					
			M	D–M	D	G	A	S
Acanthaceae	<i>Ruellia humilis</i> Nutt. (Hairy Wild-petunia)	S1 G5		X				X
Acanthaceae	<i>Ruellia strepens</i> L. (Limestone Wild-petunia)	S2S3 G4G5	X	X				X
Alismataceae	<i>Echinodorus cordifolius</i> (L.) Griseb. (Creeping Burhead)	S1 G5						X
Alismataceae	<i>Sagittaria engelmanniana</i> J.G. Sm. (Engelmann's Arrowhead)	S2 G5?						X
Alismataceae	<i>Sagittaria rigida</i> Pursh (Sessile-fruited Arrowhead)	S1 G5						X
Apiaceae	<i>Erigenia bulbosa</i> (Michx.) Nutt. (Harbinger-of-spring)	S3 G5	X					X
Apiaceae	<i>Harperella nodosa</i> (Rose) Rose (Harperella)	S1 G2						X
Apiaceae	<i>Heracleum maximum</i> Bartram (Cow-parsnip)	S3 G5	X					X
Apiaceae	<i>Zizia aurea</i> (L.) W.D.J. Koch (Common Golden-alexanders)	S3 G5				X		X
Apocynaceae	<i>Asclepias verticillata</i> L. (Whorled Milkweed)	S1S2 G4?		X				
Apocynaceae	<i>Matelea obliqua</i> (Jacq.) Woodson (Northern Spinyrod)	S1 G5						X
Apocynaceae	<i>Thysanbella difformis</i> (Walter) Pichon (Climbing Dogbane)	S2 G5		X				X
Aquifoliaceae	<i>Ilex decidua</i> Walter (Possum-haw)	S2S3 G3G4		X				
Araliaceae	<i>Panax quinquefolius</i> L. (American Ginseng)	S1 G5				X		
Aspleniaceae	<i>Asplenium resiliens</i> Kunze (Blackstem Splenwort)	S3 G5				X		
Aspleniaceae	<i>Asplenium ruta-muraria</i> L. var. <i>cryptolepis</i> (Fernald) Wherry (American Wall-rue)	S3 G5T5?		X				
Asteraceae	<i>Chrysogonum virginianum</i> L. (Virginia Green-and-gold)	S1 G5						X
Asteraceae	<i>Coreopsis tripteris</i> L. (Tall Coreopsis)	S3 G5		X				
Asteraceae	<i>Coreopsis verticillata</i> L. (Threadleaf Coreopsis)	S3 G5				X		
Asteraceae	<i>Eupatorium altissimum</i> L. (Tall Thoroughwort)	S1 G4	X					X
Asteraceae	<i>Hasteola suaveolens</i> (L.) Pojark. (Sweet Indian-plantain)	S1 G5T5						X
Asteraceae	<i>Helianthus occidentalis</i> Riddell ssp. <i>occidentalis</i> (Naked-stem Sunflower)	S2S3 G5		X				
Asteraceae	<i>Krigia dandelion</i> (L.) Nutt. (Potato Dandelion)	S3 G4						X
Asteraceae	<i>Packera antennariifolia</i> (Britton) W.A. Weber and Á. Löve (Shalebarren Ragwort)	S3 G5T5		X				
Asteraceae	<i>Solidago hispida</i> Muhl. ex Willd. var. <i>hispida</i> (Hairy Goldenrod)							

Plant family	Species name	State and global rank	Plant communities/habitats						
			M	D-M	D	G	A	S	
Asteraceae	<i>Solidago rupestris</i> Raf. (Rock Goldenrod)	S1 G4						X	
Asteraceae	<i>Solidago racemosa</i> Greene (Sticky Goldenrod)	S1 G3					X		
Asteraceae	<i>Symphoricarum shortii</i> (Lindl.) G.L. Nesom (Short's Aster)	S3S4 G5	X						
Boraginaceae	<i>Myosotis macrosperma</i> Engelm. (Bigseed Forget-me-not)	S3S4 G5	X	X					
Boraginaceae	<i>Myosotis verna</i> Nutt. (Spring Forget-me-not)	S3 G5		X					
Brassicaceae	<i>Arabis patens</i> Sull. (Spreading Rockcress)	S3 G3		X		X			
Brassicaceae	<i>Borodinia dentata</i> (Raf.) P.J. Alexander & Windham (Short's Rockcress)	S3 G5	X	X					
Campanulaceae	<i>Campanula rotundifolia</i> L. (Harebell)	S2 G5				X			
Caryophyllaceae	<i>Paronychia virginica</i> Spreng. (Virginia Whitflow-wort)	S1 G4						X	
Caryophyllaceae	<i>Sabulina michauxii</i> (Fenzl) Dillenb. & Kadereit (Rock Sandwort)	S2 G5T5			X				
Commelinaceae	<i>Commelina erecta</i> L. var. <i>erecta</i> (Erect Dayflower)	S3 G5						X	
Convolvulaceae	<i>Convolvulus spithameus</i> L. (Low Bindweed)	S2 G5T4T5				X			
Cupressaceae	<i>Thuja occidentalis</i> L. (Northern White Cedar)	S1 G5					X		
Cyperaceae	<i>Carex careyana</i> Torr. ex Dewey (Carey's Sedge)	S1 G4G5	X						
Cyperaceae	<i>Carex louisianica</i> L.H. Bailey (Louisiana Sedge)	S3 G5						X	
Cyperaceae	<i>Carex lupuliformis</i> Sartwell ex Dewey (False Hop Sedge)	S2 G4						X	
Cyperaceae	<i>Carex planispicata</i> Naczi (Flat-spiked Sedge)	S1S2 G4		X					
Cyperaceae	<i>Carex shortiana</i> Dewey (Short's Sedge)	S3S4 G5						X	
Cyperaceae	<i>Cyperus retrofractus</i> (L.) Torr. (Rough Flatsedge)	S2 G5		X		X		X	
Cyperaceae	<i>Cyperus subquarrosus</i> (Muhl.) Bauters (Smallflower Halfchaff)	S1 G5						X	
Cyperaceae	<i>Eleocharis compressa</i> Sull. var. <i>compressa</i> (Flattened Spikerush)	S1 G4						X	
Cyperaceae	<i>Trichophorum planifolium</i> (Spreng.) Palla (Bashful Bulrush)	S2 G5		X					
Cystopteridaceae	<i>Cystopteris bulbifera</i> (L.) Bernh. (Bulblet Fern)	S3 G5				X			
Euphorbiaceae	<i>Euphorbia spathulata</i> Lam. (Warty Spurge)	S1 G5						X	
Fabaceae	<i>Astragalus distortus</i> Torr. & A. Gray var. <i>distortus</i> (Ozark Milkvetch)	S2 G5				X			
Fabaceae	<i>Baptisia australis</i> (L.) R. Br. (Tall Blue Wild Indigo)	S2 G5						X	
Fabaceae	<i>Lespedeza frutescens</i> (L.) Hornemann (Violet Lespedeza)	S3 G5						X	
Fabaceae	<i>Trifolium virginicum</i> Small (Kate's Mountain Clover)	S2S3 G3				X			
Fagaceae	<i>Castanea dentata</i> (Marsh.) Borkh. (American Chestnut)	S2S3 G3		X					
Fagaceae	<i>Quercus macrocarpa</i> Michx. var. <i>macrocarpa</i> (Bur Oak)	S1S2 G5						X	
Fagaceae	<i>Quercus shumardii</i> Buckley (Shumard Oak)	S2 G5	X	X				X	
Grossulariaceae	<i>Ribes americanum</i> Mill. (American Black Currant)	S1 G5						X	

Plant family	Species name	State and global rank	Plant communities/habitats						
			M	D-M	D	G	A	S	
Grossulariaceae	<i>Ribes cynosbati</i> L. (Prickly Gooseberry)	S3 G5		X			X		
Hydrophyllaceae	<i>Hydrophyllum macrophyllum</i> Nutt. (Hairy Waterleaf)	S2 G5		X					
Hydrophyllaceae	<i>Phacelia covillei</i> S. Watson ex A. Gray (Eastern Buttercup Phacelia)	S2 G3	X	X					
Hydrophyllaceae	<i>Phacelia purshii</i> Buckley var. <i>purshii</i> (Miami-mist)	S3 G5	X						
Juglandaceae	<i>Carya laciniosa</i> (Michx. f.) W.P.C. Barton (Big Shellbark Hickory)	S1 G5	X						
Juglandaceae	<i>Juglans cinerea</i> L. (Butternut)	S2S3 G3	X						
Lamiaceae	<i>Monarda clinopodia</i> L. (Basil Beebalm)	S3S4 G5	X						
Lamiaceae	<i>Pycnanthemum virginianum</i> (L.) Durand & B.D. Jacks. ex Rob. & Fernald (Virginia Mountain-mint)	S2 G5						X	
Lamiaceae	<i>Scutellaria nervosa</i> Pursh (Veined Skullcap)	S1S2 G5		X					
Lamiaceae	<i>Scutellaria ovata</i> Hill var. <i>rugosa</i> (Alph. Wood) Fernald (Rough Heartleaf Skullcap)	S3 G5TNR			X	X			
Lamiaceae	<i>Scutellaria saxatilis</i> Riddell (Rock Skullcap)	S1 G3G4		X	X				
Lamiaceae	<i>Trichostema brachiatum</i> L. (False Pennyroyal)	S3 G5					X		
Lamiaceae	<i>Trichostema setaceum</i> Houtt. (Narrowleaf Blue Curls)	S1 G5					X		
Liliaceae	<i>Erythronium albidum</i> Nutt. (White Trout Lily)	S2 G5	X						
Malvaceae	<i>Hibiscus laevis</i> All. (Smooth Rose-mallow)	S3 G5					X	X	
Onagraceae	<i>Ludwigia decurrens</i> Walter (Wingstem Water-primrose)	S2S3 G5	X						
Onagraceae	<i>Oenothera argillicola</i> Mack. (Shale-barren Evening-primrose)	S3 G3G4					X		
Onocleaceae	<i>Matteuccia struthiopteris</i> (L.) Tod. var. <i>pensylvanica</i> (Willd.) C.V. Morton (Ostrich Fern)	S2S3 G5	X						
Orchidaceae	<i>Liparis liliifolia</i> (L.) Rich. ex Lindl. (Brown Wide-lip Orchid)	S3 G5		X					
Orobanchaceae	<i>Aureolaria flava</i> (L.) Farw. (Smooth Oak-leech)	S3 G5		X					
Phyllanthaceae	<i>Phyllanthus carolinensis</i> Walter (Carolina Leaf-flower)	S3 G5T5?						X	
Poaceae	<i>Bromus latiglumis</i> (Shear) Hitchc. (Riverbank Brome)	S1 G5	X						
Poaceae	<i>Bromus nottowyanus</i> Fernald (Satin Brome)	S3S4 G4G5	X						
Poaceae	<i>Dichanthelium aciculare</i> (Desv. ex Poir.) Gould & C.A. Clark (Needle-leaf Witchgrass)	S2? G5		X					
Poaceae	<i>Dichanthelium laxiflorum</i> (Lam.) Gould (Open-flower Witchgrass)	S1? G5		X				X	
Poaceae	<i>Leersia hexandra</i> Sw. (Southern Cutgrass)	S1 G5					X	X	
Poaceae	<i>Melica nutica</i> Walter (Two-flower Melic)	S3 G5	X	X					
Poaceae	<i>Melica nitens</i> (Scribn.) Nutt. ex Piper (Three-flower Melic)	S2 G5				X			
Poaceae	<i>Paspalum fluitans</i> (Elliot) Kunth (Water Paspalum)	S2 G5					X		
Poaceae	<i>Patis racemosa</i> (Sm.) Romasch., P.M. Peterson, & Soreng (Blackseed Ricegrass)	S2S3 G5		X				X	
Polygalaceae	<i>Polygala polygama</i> Walter (Racemed Milkwort)	S1 G5		X					

Plant family	Species name	State and global rank	Plant communities/habitats							
			M	D-M	D	G	A	S		
Polygonaceae	<i>Rumex altissimus</i> Alph. Wood (Tall Dock)	S1 G5						X		
Primulaceae	<i>Primula meadia</i> (L.) A.R. Mast & Reveal (Eastern Shooting Star)	S3 G5		X		X				
Pteridaceae	<i>Pellaea glabella</i> Mett. ex Kuhn ssp. <i>glabella</i> (Smooth Cliff-brake)	S1 G5T5				X				
Ranunculaceae	<i>Clematis viorna</i> L. (Vase-vine)	S3 G5	X	X	X	X		X		
Ranunculaceae	<i>Delphinium tricornis</i> Michx. (Dwarf Larkspur)	S3 G5		X						
Rosaceae	<i>Amelanchier nantucketensis</i> E.P. Bicknell (Nantucket Serviceberry)	S1 G3Q				X				
Rosaceae	<i>Spiraea corymbosa</i> Raf. (Rock Spiraea)	S3 G5T4?			X					
Rubiaceae	<i>Galium boreale</i> L. (Northern Bedstraw)	S1 G5					X			
Ruscaceae	<i>Maianthemum stellatum</i> (L.) Link (Starry Solomon's-plume)	S2 G5	X							
Rutaceae	<i>Ptelea trifoliata</i> L. var. <i>trifoliata</i> (Common Wafer-ash)	S3 G5	X	X				X		
Saxifragaceae	<i>Heuchera pubescens</i> Pursh (Marbled Alumroot)	S3 G4?		X		X				
Scrophulariaceae	<i>Scrophularia lanceolata</i> Pursh (American Figwort)	S3 G5					X			
Thymelaeaceae	<i>Dirca palustris</i> L. (Leatherwood)	S2 G4		X						
Trilliaceae	<i>Trillium nivale</i> Riddell (Snow Trillium)	S1 G4		X						
Valerianaceae	<i>Valeriana pauciflora</i> Michx. (Pink Valerian)	S1 G4	X							
Valerianaceae	<i>Valerianella chenopodiifolia</i> (Pursh) DC (Goosefoot Cornsalad)	S1 G5	X							
Vitaceae	<i>Vitis rupestris</i> Scheele (Sand Grape)	S1 G3							X	

Appendix 2. Plant species of conservation concern that were initially detected prior to 2008 within the Chesapeake and Ohio Canal National Historical Park, but not detected again in resurvey efforts from 2008 through 2021. State and global rank codes follow NatureServe (2021) and Maryland Natural Heritage Program (2021). Voucher specimen information includes collector name, collection number, and acronym of herbarium repository following Thiers (2023).

Plant family	Species name	Conservation rank	Last observed	Voucher specimen
Amaranthaceae	<i>Iresine rhizomatosa</i> Standl. (Bloodleaf)	S1 G5	2000	<i>Lea 987</i> TAWES
Apiaceae	<i>Cicuta bulbifera</i> L. (Bulb-bearing Water-hemlock)	S1 G5	1919	<i>Leonard 1367</i> US
Aspleniaceae	<i>Asplenium pinnatifidum</i> Nutt. (Lobed Splenewort)	S1 G4	1995	<i>Shreve s.n.</i> MIN
Asteraceae	<i>Arnica acaulis</i> (Walter) Britton, Sterns & Poggenb. (Leopard's-bane)	S1 G4	1919	<i>Ward s.n.</i> US
Asteraceae	<i>Arnoglossum reniforme</i> (Hook.) H. Rob. (Great Indian-plantain)	SHX G4	1880	<i>Ward s.n.</i> US
Asteraceae	<i>Packera paupercula</i> (Michx.) A. Löve & D. Löve var. <i>paupercula</i> (Balsam Ragwort)	S3 G5	1998	<i>Downs 5630</i> WILLI
Asteraceae	<i>Rudbeckia fulgida</i> Aiton (Common Eastern Coneflower)	S3 G5	1931	<i>Fosberg 55577</i> US
Asteraceae	<i>Rudbeckia triloba</i> L. var. <i>triloba</i> (Common Three-lobed Coneflower)	S3 G5T4T5	1940	<i>Ward s.n.</i> US
Asteraceae	<i>Silphium asteriscus</i> var. <i>trifoliatum</i> (L.) J.A. Clevinger (Threelobed Rosinweed)	S3 G4?T4?	2004	<i>Eyler s.n.</i> MARY
Asteraceae	<i>Symphiotrichum depauperatum</i> (Fernald) G.L. Nesom (Serpentine Aster)	S1 G2	1930	<i>Freeman s.n.</i> NA
Asteraceae	<i>Symphiotrichum drummondii</i> (Lindl.) G.L. Nesom (Hairy Heart-leaved Aster)	S1 G4G5T4T5	1968	<i>Lea 913</i> TAWES
Boraginaceae	<i>Lithospermum virginianum</i> L. (Virginia Marbleseed)	S1 G4	1999	<i>Boone s.n.</i> TAWES
Brassicaceae	<i>Borodinia missouriensis</i> (Greene) P.J. Alexander & Windham (Missouri Rockcress)	S1 G5	1971	<i>Baltars 4546</i> Cylburn Arboretum
Brassicaceae	<i>Cardamine douglassii</i> Britton (Purple Cress)	S3 G5	2000	<i>Smith s.n.</i> GH
Brassicaceae	<i>Rorippa aquatica</i> (Eaton) E.J. Palmer & Steyerf. (Lake Cress)	S1 G4?	1882	<i>Ward s.n.</i> US
Caprifoliaceae	<i>Symphoricarpos albus</i> (L.) Blake var. <i>albus</i> (Common Snowberry)	S1 G5T5	1995	<i>Boone s.n.</i> TAWES
Caprifoliaceae	<i>Triosteum angustifolium</i> L. var. <i>angustifolium</i> (Smooth Lesser Horse-gentian)	S1 G5	2000	<i>Brown s.n.</i> MARY
Caryophyllaceae	<i>Silene nivea</i> (Nutt.) Muhl. ex Oth. (Snowy Campion)	S1 G4?	1995	<i>Boone s.n.</i> TAWES
Ceratophyllaceae	<i>Ceratophyllum echinatum</i> A. Gray (Prickly Hornwort)	S2? G4	1982	<i>Killip 36965</i> PH
Convolvulaceae	<i>Cuscuta coryli</i> Engelm. (Hazel Dodder)	S1 G5?	1934	<i>Killip 31293</i> US
Convolvulaceae	<i>Cuscuta polygonorum</i> Engelm. (Smartweed Dodder)	S1 G5	1961	<i>Killip 13258</i> US
Cyperaceae	<i>Carex albusina</i> E. Sheld. (White Bear Sedge)	S3 G5	2005	<i>Lea 880</i> TAWES
Cyperaceae	<i>Carex copulata</i> (L.H. Bailey) Mack. (Spreading Sedge)	S1? G5T3T5	2000	<i>Lea 1376</i> TAWES
Cyperaceae	<i>Carex cristatella</i> Britton (Crested Sedge)	S1? G5	2000	<i>Lea 1220</i> TAWES
Cyperaceae	<i>Carex davisi</i> Schwein. & Torr. (Davis's Sedge)	S1 G4G5	2001	<i>Lea 2442</i> TAWES
Cyperaceae	<i>Carex decomposita</i> Muhl. (Cypress-knee Sedge)	S1 G3	2007	<i>Chase 7552</i> BRY

Plant family	Species name	Conservation rank	Last observed	Voucher specimen
Cyperaceae	<i>Carex digitalis</i> Willd. var. <i>macropoda</i> Fernald (Long-spiked Slender Woodland Sedge)	S1? G5TNR	2000	Lea 1065 TAWES
Cyperaceae	<i>Carex emoryi</i> Dewey (Emory's Sedge)	S3 G5	2005	Lea 2448 TAWES
Cyperaceae	<i>Carex hirtifolia</i> Mack. (Pubescent Sedge)	S3 G5	2006	Lea 1027 TAWES
Cyperaceae	<i>Carex hitchcockiana</i> Dewey (Hitchcock's Sedge)	S1 G5	1999	Lea 759 TAWES
Cyperaceae	<i>Carex pellita</i> Muhl. (Woolly Sedge)	S2? G5	1898	Steele s.n. US
Cyperaceae	<i>Carex sparganioides</i> Muhl. ex Willd. (Bur-reed Sedge)	S3 G5	2000	Lea 1480 TAWES
Cyperaceae	<i>Carex straminea</i> Willd. ex Schkuhr (Straw Sedge)	S1S2 G5	1886	Boone s.n. TAWES
Cyperaceae	<i>Carex striatula</i> Michx. (Lined Sedge)	S3 G5	1921	Lea 1378 TAWES
Cyperaceae	<i>Carex tenera</i> Dewey (Quill Sedge)	SHX G5	2000	Lea 1697 TAWES
Cyperaceae	<i>Cyperus refractus</i> Engelm. ex Boeckeler (Reflexed Flatsedge)	S2? G5	1998	Lea 929 TAWES
Cyperaceae	<i>Fimbristylis annua</i> (All.) Roem. & Schult. (Annual Fimbr)	S3 G5	1905	House 1365 US
Diplaziopsidaceae	<i>Diplaziopsis pycnocarpa</i> (Spreng.) M.G. Price. (Glade Fern)	S2 G5	1999	Thompson s.n. TAWES
Ericaceae	<i>Pyrola chlorantha</i> Sw. (Greenflower Wintergreen)	SH G5	1898	Steele s.n. US
Fabaceae	<i>Astragalus canadensis</i> L. var. <i>canadensis</i> (Canada Milkvetch)	S1 G5T5	2000	Boone s.n. TAWES
Fabaceae	<i>Desmodium laevigatum</i> (Nutt.) DC. (Smooth Tick-trefoil)	S3 G5	1910	Ditman s.n. MARY
Fabaceae	<i>Desmodium obtusum</i> (Muhl. ex Willd.) DC. (Stiff Tick-trefoil)	S1 G4G5	1998	Chickering s.n. US
Fabaceae	<i>Lathyrus palustris</i> L. (Marsh Pea)	S1 G5	1983	Judy 9 MARY
Fabaceae	<i>Phaseolus polystachios</i> (L.) Britton, Sterns & Poggenb. (Wild Kidney Bean)	S3 G5	1999	Baker s.n. GMUF
Fabaceae	<i>Senna marilandica</i> (L.) Link (Maryland Wild Senna)	S3 G5	1998	Wheeler 5626 RSA
Fabaceae	<i>Trifolium reflexum</i> L. (Buffalo Clover)	SHX G3G4	1902	Pollard s.n. US
Gentianaceae	<i>Gentiana villosa</i> L. (Striped Gentian)	S1 G4	1986	Kearney 179 US
Iridaceae	<i>Iris cristata</i> Aiton (Dwarf Crested Iris)	S1 G5	2000	Chickering s.n. CM
Iridaceae	<i>Iris virginica</i> L. (Southern Blue Flag)	S3 G5	1995	Boone s.n. TAWES
Isoetaceae	<i>Isoetes engelmannii</i> A. Braun (Engelmann's Quillwort)	S3 G5	1899	Williamson s.n. PH
Lamiaceae	<i>Pycnanthemum clinopodioides</i> Torr. & A. Gray (Basil Mountain-mint)	SH G1G2	1954	Sargent 7055 US
Lamiaceae	<i>Pycnanthemum torreyi</i> Benth. (Torrey's Mountain-mint)	S1 G2	1908	Dowell 5381 US
Lamiaceae	<i>Pycnanthemum verticillatum</i> (Michx.) Pers. (Whorled Mountain-mint)	S2 G5	1951	Killip 41367 US
Lamiaceae	<i>Scutellaria incana</i> Biehler var. <i>incana</i> (Hoary Skullcap)	S3 G5T5	2005	Boone s.n. TAWES
Lamiaceae	<i>Scutellaria leonardii</i> Epling (Shale-barren Skullcap)	S2 G4	2004	Freeman s.n. NA
Lamiaceae	<i>Scutellaria serrata</i> Andrews (Showy Skullcap)	S3 G4G5	1999	Hunnell 5195 GH
Lamiaceae	<i>Stachys aspera</i> Michx. (Rough-leaved Hedge-nettle)	S1 G4?	1910	McAtee 1681 US
Lythraceae	<i>Lythrum alatum</i> Pursh (Northern Winged Loosestrife)	S1 G5	2000	Killip 31898 US

Plant family	Species name	Conservation rank	Last observed	Voucher specimen
Malvaceae	<i>Ripartosida hermaphrodita</i> (L.) Weakley & D.B. Poind. (Virginia-mallow)	S1 G3	2000	Killip 32626 US
Melanthiaceae	<i>Chamaelirium luteum</i> (L.) A. Gray (Fairy-wand)	S2 G5	1995	Storey s.n. MARY
Orchidaceae	<i>Corallorhiza wisteriana</i> Conrad (Spring Coralroot)	S1 G5	1915	Kearney s.n. US
Orchidaceae	<i>Liparis loeselii</i> (L.) Rich. (Yellow Wide-lip Orchid)	S3 G5	1983	Riefner 80-244 MARY
Orchidaceae	<i>Triphora trianthophoros</i> (Sw.) Rydb. var. <i>trianthophoros</i> (Three Birds Orchid)	S1 G4?	1998	Pollard s.n. US
Orobanchaceae	<i>Agalinis auriculata</i> (Michx.) S.F. Blake (Earleaf Foxglove)	S1 G3	1999	Killip 31940 PH
Plantaginaceae	<i>Mecardonia acuminata</i> (Walter) Small var. <i>acuminata</i> (Mecardonia)	S2 G5T5	2007	Frye 5542 TAWES
Plantaginaceae	<i>Veronica scutellata</i> L. (Narrowleaf Speedwell)	S1 G5	1897	Steele s.n. US
Poaceae	<i>Aristida lanosa</i> Muhl. ex Elliott (Woollysheath Three-awn)	S1 G5	1898	Holm s.n. CU
Poaceae	<i>Bouteloua curtipendula</i> (Michx.) Torr. var. <i>curtipendula</i> (Side-oats Grama)	S2 G5	1995	Riefner 81-701 MARY
Poaceae	<i>Muhlenbergia capillaris</i> (Lam.) Trin. (Hairgrass)	S1 G5	1998	Boone s.n. TAWES
Poaceae	<i>Sporobolus clandestinus</i> (Biehler) Hitchc. (Rough Dropseed)	S2 G5	2005	Lea 865 TAWES
Polypalaceae	<i>Polygala senega</i> L. var. <i>senega</i> (Northern Senega Snakeroot)	S2 G4G5	1921	Chase 6885 US
Polyodiaceae	<i>Pleopeltis michauxiana</i> (Weath.) Hickey & Sprunt (Resurrection Fern)	S3 G5T5	1939	Hay 181 MICH
Potamogetonaceae	<i>Potamogeton foliosus</i> Raf. var. <i>foliosus</i> (Leafy Pondweed)	S2 G5	2005	Lea 3532 TAWES
Primulaceae	<i>Steironema hybridum</i> (Michx.) Raf. ex B.D. Jackson (Lowland Loosestrife)	S2 G5	1985	Freeman s.n. DUKE
Primulaceae	<i>Steironema lanceolatum</i> (Walter) Gray (Lanceleaf Loosestrife)	S3 G5	2000	Boone s.n. TAWES
Ranunculaceae	<i>Ranunculus flabellaris</i> Raf. (Yellow Water Crowfoot)	S1 G5	1999	Cook s.n. MARY
Ranunculaceae	<i>Troutvetteria carolinensis</i> (Walter) Vail (Tassel-rue)	S3 G5	2000	Williamson s.n. PH
Rosaceae	<i>Amelanchier sanguinea</i> (Pursh) DC. (Roundleaf Serviceberry)	S1 G5	1995	Ashe s.n. US
Rosaceae	<i>Amelanchier spicata</i> (Lam.) K. Koch (Dwarf Serviceberry)	S2 G5	2006	Frye MO#9 TAWES
Rosaceae	<i>Dryomacallis arguta</i> (Pursh) Rydb. (Tall Drymocalis)	SH G5	1985	Killip 31995 US
Rosaceae	<i>Geum allepticum</i> Jacq. (Yellow Avena)	S1 G5	1933	Killip 31074 US
Rubiaceae	<i>Spermacoce glabra</i> Michx. (Smooth Buttonweed)	S1 G4G5	2000	Fleming 6143 WILLI
Salicaceae	<i>Salix interior</i> Rowlee (Sandbar Willow)	S1 G5	1902	Ball 61 US
Solanaceae	<i>Physalis virginiana</i> Mill. (Virginia Ground-cherry)	S3 G5	1990	Bright s.n. CM
Valerianaceae	<i>Valerianella umbilicata</i> (Sull.) Alph. Wood (Navel Cornsalad)	SHX G3G5	1919	Steele s.n. US
Violaceae	<i>Cubelium concolor</i> (T.F. Forst.) Raf. ex Britton & A. Br. (Eastern Green-violet)	S3 G5	2005	Boone s.n. TAWES