



Inventory of Rare, Threatened, and Endangered Plant Species to Inform Woodland Management at Antietam National Battlefield



From left to right, top row: *Liparis loeselii*, *Liparis liliifolia*, *Delphinium tricorne*, *Ruellia strepens*, *Matelea obliqua*. Bottom row: *Cystopteris bulbifera*, *Primula meadia*, *Cubelium concolor*, *Symphyotrichum shortii*, *Scutellaria nervosa*.

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Abstract

Antietam National Battlefield (ANTI), established in 1890, preserves the cultural and natural resources tied to the 1862 Battle of Antietam. In addition to protecting historic farmsteads, monuments, and the battlefield landscape, ANTI is increasingly recognized as an important refuge for native vegetation, rare plant species, and water resources in a region experiencing ongoing development. Guided by its 2021 Cultural Landscape Report, the park has launched new management strategies focused on watershed protection, grassland, and forest block restoration.

Because these restoration efforts may affect rare, threatened, and endangered (RT&E) species, ANTI conducted a comprehensive inventory of RT&E plants across five key forest tracts—Snively, Roulette, Union Advance, West, and Sherrick Woods—covering 172 acres. Surveys between June 2024 and June 2025 recorded 326 occurrences of 17 RT&E target species, including two species new to the park. The study found that RT&E species are disproportionately associated with historically forested areas (78% of occurrences fell within 1936 forest boundaries), steep slopes, Opequon-Rock outcrop soils, and Ridge and Valley Limestone Oak-Hickory Forest communities.

Results highlight the lasting influence of historical land use, geology, and limited dispersal ability on present-day species distributions. Many RT&E species remain confined to limestone outcrops and steep slopes that escaped agricultural clearing, while secondary forests on former farmland often lack suitable conditions for recolonization. Dispersal limitations, competition with invasive plants, deer herbivory, and site-specific factors such as dense pawpaw thickets further constrain population expansion.

Management recommendations include prioritizing protection of calcareous forest habitats, maintaining continuity of historically forested areas, mitigating invasive species, and addressing deer impacts. These findings will inform future restoration planning, deer management, trail siting, and long-term monitoring to safeguard ANTI's most sensitive plant populations while achieving broader habitat restoration goals.

Acknowledgments

We thank the National Park Service Inventory and Monitoring Division and Antietam National Battlefield for the opportunity to work in this remarkable landscape. We are especially grateful to Sarah Brown and Joe Calzarette for their generous time and thoughtful advice during the design and planning of this project. We also appreciate the assistance of the park staff at the visitor center, who accommodated our frequent visits to pick up and return equipment. Finally, we thank Towson University for supporting Vanessa Beauchamp's sabbatical during the early stages of this project. This project was made possible through the support from the National Park Service Inventory and Monitoring Division.

Introduction

Park Resource Management Issues

Designated in 1890, Antietam National Battlefield (ANTI) serves to preserve, protect, restore, and interpret the resources associated with the Battle of Antietam and its legacy. As a national battlefield, the park's highest priority resources are those pertaining to the Battle of Antietam, such as the many historic farmsteads, monuments, and maintaining the 1862 battlefield landscape. However, as the area surrounding ANTI continues to be developed, the park is quickly becoming a refuge for native and rare vegetation and wildlife and proving to be an influential protector of water resources.

Considering ANTI's increasing value as a refuge for natural resources as well as guidance from the park's Cultural Landscape Report released in 2021 (Evans 2021), the park is moving forward with new management strategies intent on Antietam Creek watershed protection. These new management strategies focus heavily on grassland and forest block restoration, with reforestation efforts beginning in the spring of 2023 and grassland restoration in 2024.

In the wake of these restoration efforts, the landscape of ANTI is projected to change and likely impact some of the park's rarest plant species. Therefore, rare, threatened, and endangered (RT&E) species found in restricted areas of the park need to be re-assessed to determine the best approach to protect and preserve these species in a changing environment. A previous vegetation inventory completed in 1997 addressed RT&E species (Heritage and Biodiversity Conservation Programs 1997), but it is now outdated and did not include new acreage that was added in the early 2000s. A 2005 vegetation inventory and mapping effort did not directly address RT&E species, though various RT&E species were detected through their sampling efforts.

ANTI has several forested areas across the 1,900 acres that the park directly oversees. This study focuses efforts on five wooded areas in the park—Snively, Roulette, Union Advance, West, and Sherrick—that together cover 172 acres (Figure 1). These woods serve as the largest tracts of natural habitat in an otherwise agricultural and pastoral landscape with a history of cultivation and disturbance tracing back to the late 1700s (Evans 2021). Vegetation communities of interest present in these woods range from successional tulip poplar forest to rich floodplain forest to upland, limestone oak-hickory forest. Historically, these upland sites of limestone oak-hickory forest, particularly those located on rocky slopes and ridges deemed unsuitable for agriculture, have harbored the greatest richness of RT&E plant species (Evans 2021; Heritage and Biodiversity Conservation Programs 1997). These woods were also prioritized as focus areas in the park because of their proximity to identified sites for reforestation to fill in forest blocks. Therefore, any RT&E species recorded in these woods will be important resources to consider as the park works to expand and restore these forested areas.

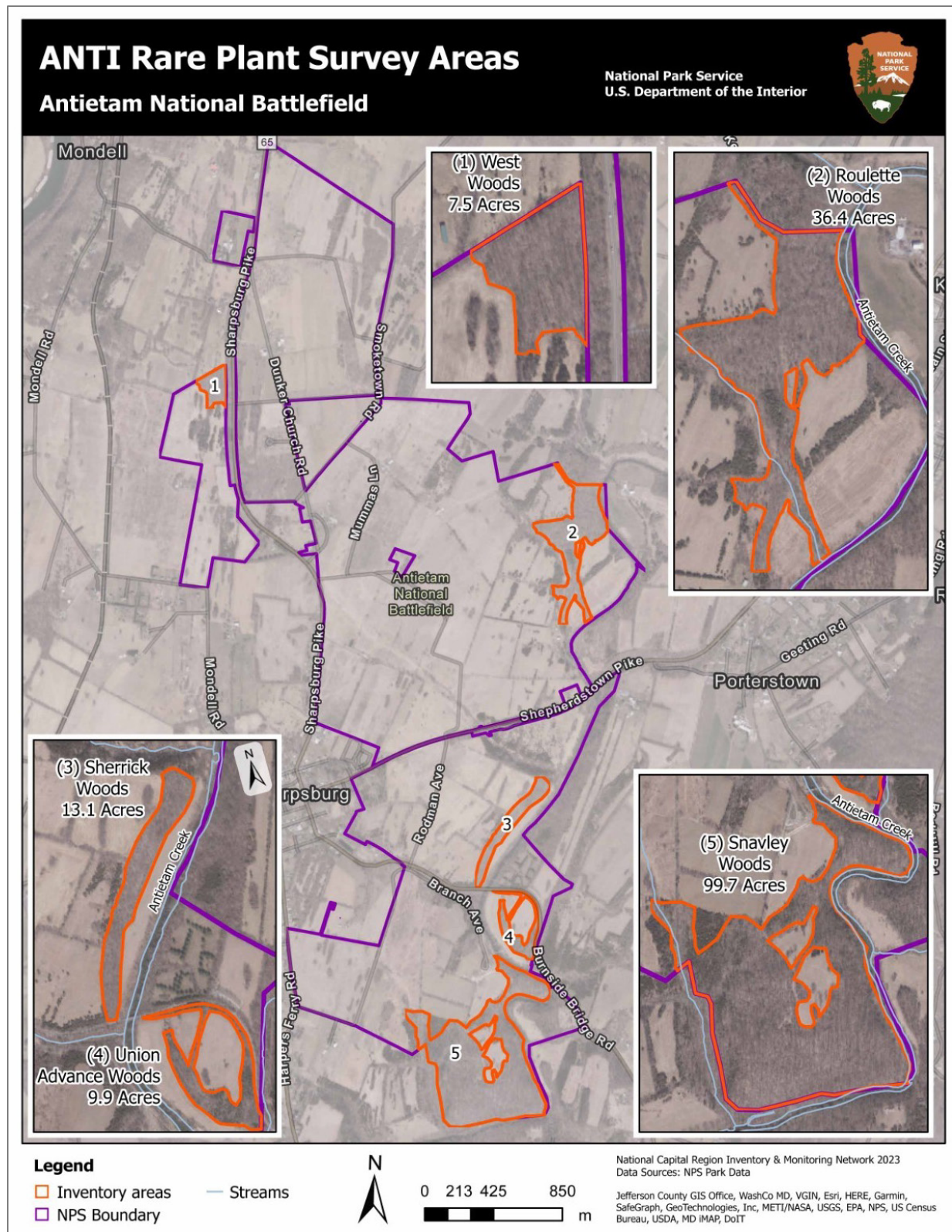


Figure 1. Map showing the park boundary (purple) and five forested areas surveyed for this project (orange).

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The target species list consists of 24 species with State Rank S1–S3 (Table 1). This species list is derived from previous vegetation inventories and monitoring conducted at ANTI, but also includes other RT&E species known to occur in the various natural communities included in the project.

Table 1. Target species list of state and global ranked species. Derived from a list of species previously documented at Antietam National Battlefield and other RT&E species known to occur in the various natural communities included in the project. Source for each record is Engelhardt (2005) except where footnoted. State and global ranks are taken from the Maryland Natural Heritage Program's Rare Threatened and Endangered Plants of Maryland (2021). Range ranks (e.g., S2S3) indicate a range of uncertainty in the rank.

Species	Family	State Rank	Global Rank	Historic Points ^A
<i>Asplenium resiliens</i> Kunze ^B	Aspleniaceae	S1	G5	0
<i>Carex hitchcockiana</i> Dewey	Cyperaceae	S1	G5	1
<i>Carex sparganioides</i> Muhl. ex Willd.	Cyperaceae	S3	G5	3
<i>Castanea dentata</i> (Marshall) Borkh.	Fagaceae	S2S3	G3	0
<i>Clematis viorna</i> L. ^C	Ranunculaceae	S3	G5	1
<i>Cubelium concolor</i> (T.F.Forst.) Raf.	Violaceae	S3	G5	1
<i>Cystopteris bulbifera</i> (L.) Bernh.	Aspleniaceae	S3	G5	0
<i>Delphinium tricornis</i> Michx.	Ranunculaceae	S3	G5	2
<i>Erigenia bulbosa</i> (Michx.) Nutt.	Apiaceae	S3	G5	1
<i>Heracleum maximum</i> W.Bartram	Apiaceae	S3	G5	1
<i>Hydrastis canadensis</i> L.	Ranunculaceae	S2	G3	7
<i>Juglans cinerea</i> L.	Juglandaceae	S2S3	G3	2
<i>Liparis liliifolia</i> (L.) Rich. ex Lindl.	Orchidaceae	S3	G5	4 (<i>Liparis</i> sp.)
<i>Liparis loeselii</i> (L.) Rich.	Orchidaceae	S1S2	G5	4 (<i>Liparis</i> sp.)
<i>Monarda clinopodia</i> L.	Lamiaceae	S3S4	G5	0
<i>Panax quinquefolius</i> L.	Araliaceae	S2S3	G3G4	4
<i>Physalis virginiana</i> Mill.	Solanaceae	S3	G5	0
<i>Primula meadia</i> (L.) A.R.Mast & Reveal	Primulaceae	S3	G5	1
<i>Ribes cynosbati</i> L.	Grossulariaceae	S3	G5	0
<i>Ruellia strepens</i> L. ^D	Acanthaceae	S2S3	G4G5	0
<i>Scutellaria incana</i> Biehler ^C	Lamiaceae	S3	G5T5	1

^A Points provided as a shapefile, year collected unknown.

^B Teague et al. (2020).

^C Historic point outside of designated search area.

^D Sarah Brown, personal communication, 2023.

^E Heritage and Biodiversity Conservation Programs (1997).

Table 1 (continued). Target species list of state and global ranked species. Derived from a list of species previously documented at Antietam National Battlefield and other RT&E species known to occur in the various natural communities included in the project. Source for each record is Engelhardt (2005) except where footnoted. State and global ranks are taken from the Maryland Natural Heritage Program's Rare Threatened and Endangered Plants of Maryland (2021). Range ranks (e.g., S2S3) indicate a range of uncertainty in the rank.

Species	Family	State Rank	Global Rank	Historic Points ^A
<i>Scutellaria nervosa</i> Pursh	Lamiaceae	S1S2	G5	1
<i>Symphyotrichum shortii</i> (Lindl.) G.L.Nesom	Asteraceae	S3S4	G5	0
<i>Zizia aurea</i> (L.) W.D.J. Koch ^{C, E}	Apiaceae	S3	G5	0

^A Points provided as a shapefile, year collected unknown.

^B Teague et al. (2020).

^C Historic point outside of designated search area.

^D Sarah Brown, personal communication, 2023.

^E Heritage and Biodiversity Conservation Programs (1997).

As ANTI implements new management strategies to best protect its natural resources, new and updated data are necessary to ensure proper and strategic resource protection. This inventory of RT&E plants within the park's natural forests will provide much-needed data on the status of RT&E species as the park moves forward with augmenting and restoring habitat blocks, as well as informing deer management, trail relocations, and monitoring efforts undertaken by park staff.

Causes of Rarity for Plant Species

Rare species are typically characterized by small population sizes, narrow geographic ranges, or both. Several factors, including the total number of populations of a plant, the sizes of those populations, the range and extent of the area a species occupies, the short- and long-term variability in population size and geographic extent, and the scope, severity, and immediacy of threats faced by a species, all influence the classification of a plant species as rare (Rabinowitz 1981). A variety of abiotic, biotic, and societal factors can contribute to rarity.

Abiotic factors, including climate, topography, and soil conditions, can influence plant population dynamics. Some rare plants may have extremely narrow tolerances for factors such as soil pH, moisture, and nutrient availability, which restrict their ideal habitat to small geographical regions (Wamelink et al. 2014). These specialized habitat requirements make many rare plants more susceptible to extinction. Antietam National Battlefield is located within the Great Valley section of the Ridge and Valley physiographic province and sits atop Cambrian Elbrook Limestone and Cambrian–Ordovician Conococheague Limestone (Thornberry-Ehrlich 2025) and botanists have long recognized the distinct floras that occupy calcareous substrate (Ewald 2003; Fernald 1907). These soils typically have a high pH (5.5–8), which can cause nutrient limitations, particularly of phosphorus, that lead to floristic specialization. Many calciphile species can tolerate or even thrive in non-calcareous soils, but are relegated to these high pH refugia in the face of competition with other

plant species (Tansley 1917; Veblen and Young 2009), which contributes to their rarity. In Pennsylvania, calciphile taxa make up just 15.3% of the flora but represent 23.8% of all rare taxa. Likewise, almost 80% of the plant taxa found exclusively in calcareous habitats in Pennsylvania are rare (McPherson 2013). Of the 24 target RT&E species for this project, 14 are described as primarily occurring on limestone substrates (Maryland Natural Heritage Program 2021).

Plants may also be rare due to biotic factors, including interactions with pollinators (Knapp et al. 2024; Moeller et al. 2012; Schiller et al. 2000), mutualistic or pathogenic bacteria and fungi (Dreaden et al. 2024; Huguët and Rudgers 2010; Klironomos 2002), competition from invasive plant species (Haines et al. 2024; Hernández-Yáñez et al. 2016), or impacts from overabundant herbivores (Rooney 2001; Rooney and Waller 2003). Of the RT&E species examined in this project, *Castanea dentata* populations have been decimated by the spread of Chestnut blight fungus (*Cryphonectria parasitica*) since the early 1900s (Rigling and Prospero 2018), and *Juglans cinerea* has been impacted by *Ophiognomonia clavignenti-juglandacearum*, the fungus that causes butternut canker, since the 1960s (van der Meer et al. 2025). Growth and reproduction of orchids are dependent on association with specific species of mycorrhizal fungi, and the two *Liparis* species on the target list may be limited by the availability of this fungus in the soil (McCormick et al. 2012). According to the Maryland Natural Heritage Program (2021) seven target species (*C. sparganioides*, *H. maximum*, *H. canadensis*, *L. loeselii*, *M. clinopodia*, *R. strepens*, and *S. nervosa*) are threatened by the encroachment of exotic species, including Japanese knotweed (*Reynoutria japonica*), which is invading floodplain forests in the region. The New Jersey Department of Environmental Protection identified encroachment by invasive species as a major threat to *H. canadensis* (Dodds 2024), *H. concolor* (Johnson 2022) and *R. cynosbati* (Johnson 2025). Herbivory pressure, particularly by white-tailed deer in the Mid-Atlantic United States, can also contribute to rarity (Miller et al. 1992; Rooney 2001; Rooney and Waller 2003).

Rarity in plants may also be driven by plant characteristics that limit effective reproduction or dispersal. Some rare plant species have been shown to have smaller reproductive structures and are less successful in fruit production through self-pollination than more common plants (Boyd et al. 2022). Limiting the production of fruits, flowers, and seeds has a negative effect on migratory abilities, further reinforcing scarcity in a specific region. Seed germination requirements and seed dispersal mode can also contribute to rarity and make these species more susceptible to environmental changes. For example, *D. tricornis* seeds have morphophysiological dormancy that can only be broken by exposure to temperatures of 5°C (41°F) for 10–12 weeks (Baskin and Baskin 1994). While this cold stratification requirement ensures that seedlings of *D. tricornis* emerge in late winter or early spring before the canopy closes, it also makes this species vulnerable to the increased temperatures associated with global climate change and may limit the microsites where this species will be successful in the future.

An overarching factor that both directly and indirectly affects plant population dynamics is human interference. Overutilization has impacted nearly 2% of the species listed as rare in the United States (Leu et al. 2019), including *P. quinquefolius*, where illegal harvesting has reduced population sizes and has contributed to this listing of this species as rare (S2S3) in Maryland (Maryland Natural

Heritage Program 2021). The same meta-analysis (Leu et al. 2019) found that the largest threat to rare species in the United States is habitat modification, impacting 81% of the species listed under the Endangered Species Act. Deforestation and the development of natural areas for agricultural or commercial purposes is a major cause of habitat loss. The intense, prolonged disturbance that accompanies many agricultural practices causes changes to soil properties and vegetation communities that can last for dozens to hundreds of years after an area has been reforested (Cramer et al. 2008; Dupouey et al. 2002; Foster et al. 2003).

Any process that reduces the size of a population can be reinforced by mechanisms that are particularly impactful to small populations. Populations of rare plants often show much lower genetic diversity compared to those of more common plant species (Chen et al. 2014), causing inbreeding depression and susceptibility to random genetic drift. This reduction in genetic variation can lead to loss of certain alleles or traits, which can also limit the ability of the population to adapt to environmental stresses or extremes. This extinction vortex can create a self-reinforcing cycle in which small population size, loss of genetic diversity, and environmental pressures interact to accelerate a species' decline toward extinction (Forester et al. 2022).

Methods

Survey Preparation

Species Identification

The target plant species list consisted of species with State Rank S1–S3 (Table 1). This species list was derived from previous vegetation inventories and monitoring, but is not comprehensive and likely outdated. A shapefile of known RT&E points was provided by park personnel (Figure 2).

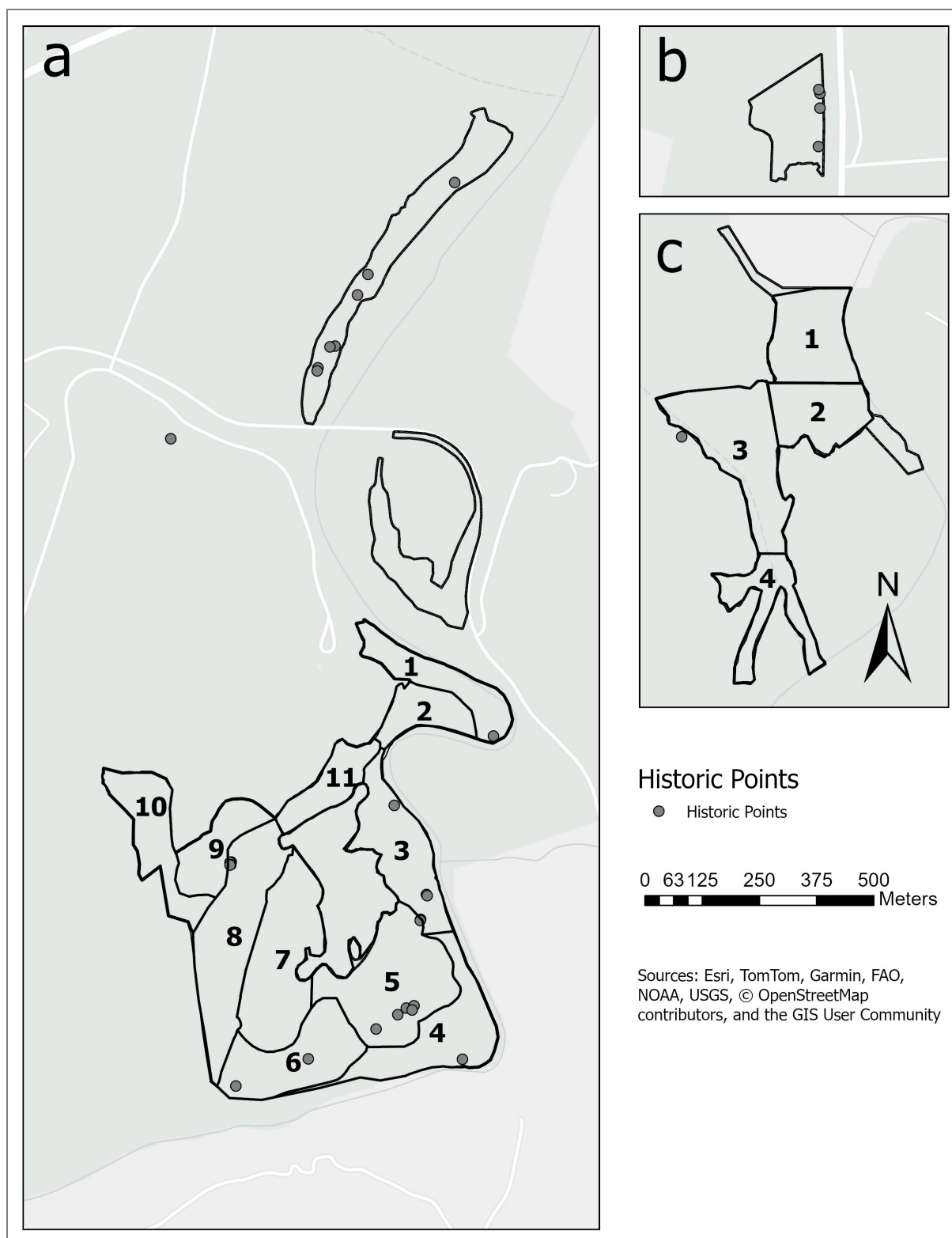


Figure 2. Locations of occurrences of target RT&E species documented in previous vegetation surveys at (a; top to bottom) Sherrick, Union Advance, and Snively Woods, (b) West Woods, and (c) Roulette Woods at ANTI.

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We researched the flowering time / main visibility period for each of the target species to identify the optimal survey window for each (see Appendix). We determined that targeted trips to look for *E. bulbosa*, *D. tricornis*, and potentially *H. canadensis* and *P. meadia* would have to be conducted during the spring, but our planned search window of June–September would be sufficient to map all other species during the period when identifying features would be present. We also compiled a field guide for all target species, which included photographs, major identification features, a species description, information on preferred habitats, and details about similar-looking species. We also examined specimens available in the Towson University herbarium (BALT) and included photographs of these specimens in the field guide.

Site Descriptions and Search Priorities

Sites surveyed for occurrences of RT&E plants include five forested areas encompassing 172 acres (Figure 1). The West Woods is a semi-natural woodlot that is a fragment of a historically larger managed woodlot footprint. The four natural forests, known as Snavelly Woods, Union Advance Woods, Sherrick Woods, and Roulette Woods, are some of the few forested areas in the park without a history of cultivation due to their rocky and steep sloping topography, and are most likely to harbor RT&E species. We made four trips between November 9, 2023, and December 22, 2023, and five trips between March 8, 2024, and May 23, 2024, to scout each of the forest areas. Due to their size and diversity, we divided Roulette Woods into four zones and Snavelly Woods into 11 zones based on topography and dominant vegetation to facilitate searching these areas (Figure 3). During these initial trips, we identified priority areas for surveying (Figure 4) based on the level of disturbance of the site and the species composition of the overstory vegetation. Descriptions of overstory vegetation of these forests are taken from the Federal Geographic Data Committee's U.S. National Vegetation Classification database and were provided as a shapefile by park personnel.

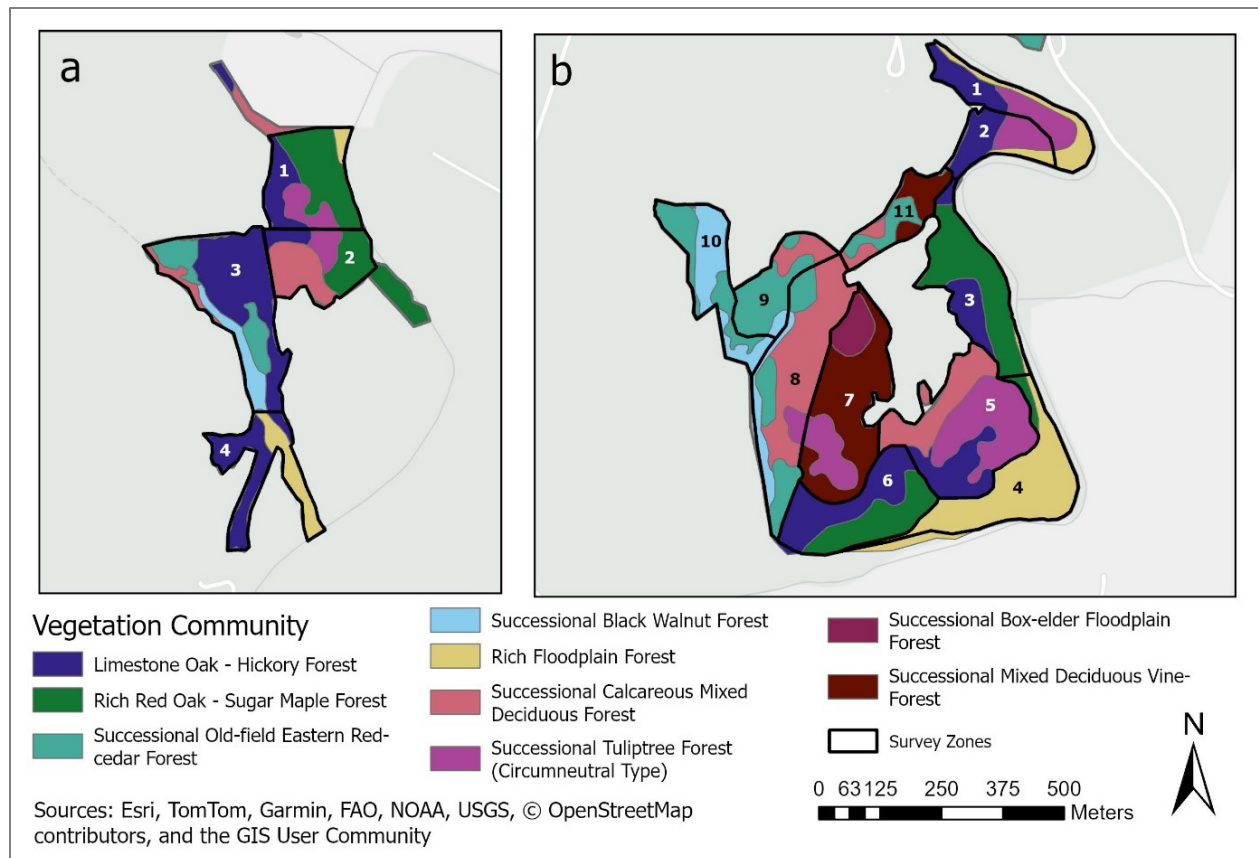


Figure 3. Survey zones delineated in (a) Roulette Woods and (b) Snavelly Woods, based on overstory vegetation, community type, and topography.

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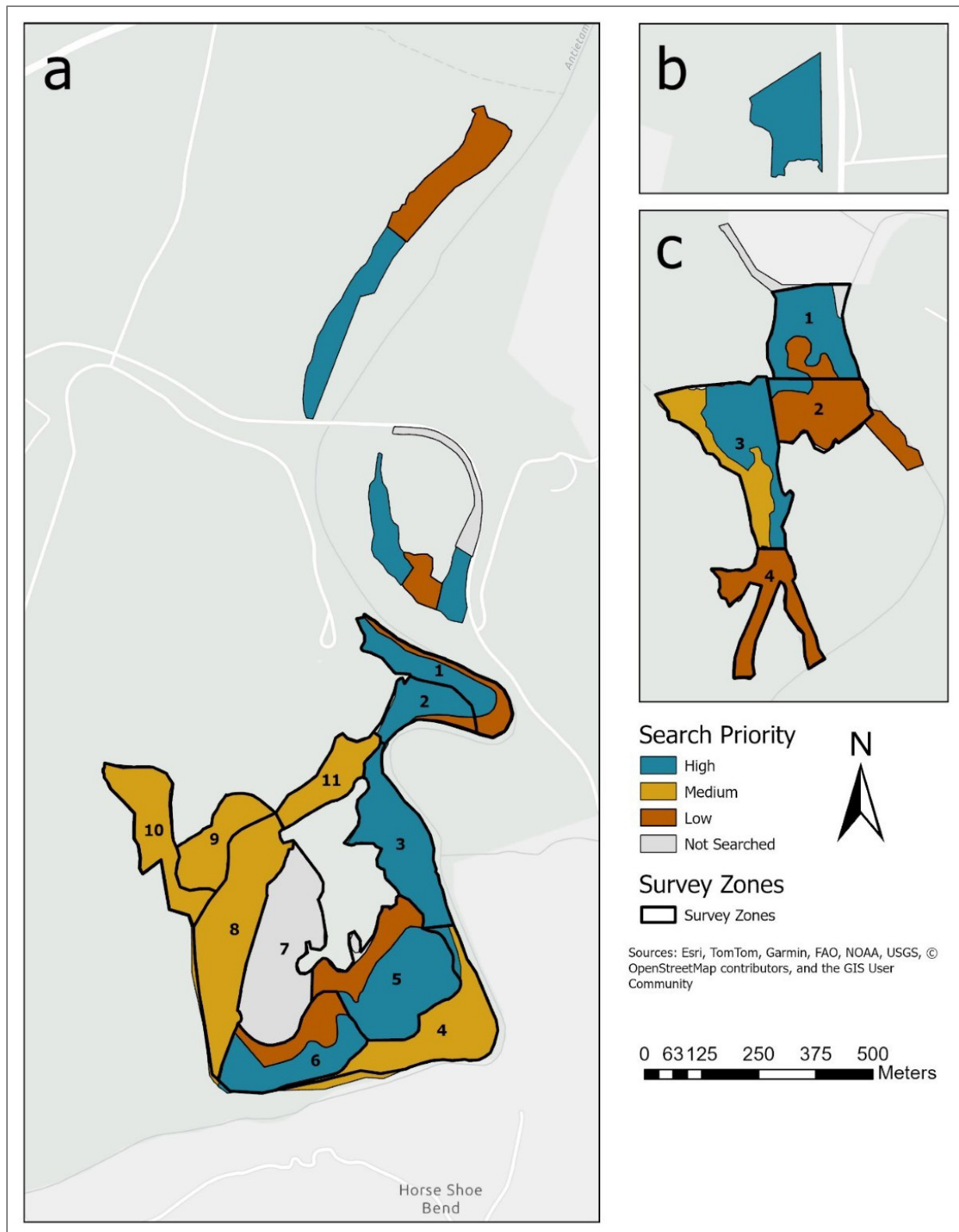


Figure 4. Search priority for different sections of (a; top to bottom) Sherrick, Union Advance, and Snavelly Woods, (b) West Woods, and (c) Roulette Woods at ANTI.

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The West Woods woodlot is 7.5 acres of Limestone Oak-Hickory Forest with an understory of dense *Asimina triloba*. It is bordered by Successional Mixed Deciduous Forest to the south. This fragment has likely not experienced any woodlot management efforts—thinning, weeding, or plantings—since the early 1900s and could serve as suitable habitat for RT&E species. Historic points collected prior to this survey and provided by ANTI natural resource management personnel show that *J. cinerea* and *C. sparganioides* have been recorded in this woodlot (Figure 2). Except for the southern edge of this woodlot, which did not extend quite as far as the provided map showed and had invasive shrubs colonizing the area adjacent to the farm field, we prioritized this entire woodlot for searching.

Roulette Woods is an intermediate-sized forest stand (36.4 acres) with a mix of forest types. This forest tract has some history of cultivation but has converted, since the battle, into the second-largest forest block in the park. Roulette Woods was not included in the 1997 RT&E Inventory, having been acquired in 1998, and is, therefore, “new” territory and a high priority for this inventory. *Scutellaria incana* has been found along the stream adjacent to these woods, but there are no RT&E species recorded in the remainder of this portion. The areas circumscribed by the Ridge and Valley Limestone Oak-Hickory Forest, Central Appalachian Rich Red Oak-Sugar Maple Forest in zones 1 and 3 were high-quality habitat with large trees and minimal areas of invasive shrubs or dense *Microstegium vimineum*. We prioritized these sections for searching. The Successional Black Walnut Forest and Successional Red-cedar Forest in zone 3 were more disturbed with more exotic species in the understory, and we gave this area an intermediate priority for searching. Zone 2, in the central core of this area, was dominated by Successional Calcareous Mixed Deciduous Forest and Successional Tuliptree Forest, and zone 4, in the southern sections of this area contained Ridge and Valley Limestone Oak-Hickory Forest and Rich Floodplain Forest. Both of these zones were more disturbed than zones 1 and 3, with many areas dominated by thick carpets of *M. vimineum*, and we assigned these sections a low search priority. In agreement with park personnel, we removed the highly disturbed northern extension of this property from our search list.

Sherrick Woods comprises 5.0 acres of Limestone Oak-Hickory Forest at the south end, approximately 3 acres of Successional Mixed Deciduous Forest in the northwest corner, and 4.2 acres of Successional Box-elder Floodplain Forest in the northeast corner. This forest tract, particularly at the south end, is exceptionally steep, and *C. concolor* has been recorded in this section (Figure 2). The northern section of the Sherrick Woods was heavily overgrown with *Rosa multiflora* and *Elaeagnus umbellata*, to the point that some of this area was essentially inaccessible. We prioritized searching the south end, except for several specific attempts to relocate the *Liparis* sp. recorded in the northern section (Figure 2).

Union Advance Woods contains 2.3 acres of Limestone Oak-Hickory Forest at the north end, which we prioritized for searching, and 5.6 acres of Old-field Eastern Red-cedar Forest at the south end. Much of the Red-cedar Forest was overgrown with dense *E. umbellata*, except for a pocket of habitat adjacent to the 11th Connecticut Infantry Regiment monument. We planned to search this pocket more intensely, but set the remainder of this section as a lower priority. The sliver of Calcareous Black Locust Successional Forest adjacent to Burnside Bridge Road was very overgrown with invasive shrubs and was not searched further. There are no known RT&E species in this forest tract.

Snively Woods is the largest of the target forested survey areas (100 acres). We determined that much of Snively Ford zones 1, 2, 3, 5, and 6, which were dominated by Ridge and Valley Limestone Oak-Hickory Forest, Central Appalachian Rich Red Oak-Sugar Maple Forest, and Successional Tuliptree Forest, were high-quality habitats and should be subject to intense searching for target species. The floodplain (zone 4 and part of zone 1), the northern portions of zones 5 and 6, and areas in the northern part of these woods (zones 8–11) were more disturbed and less likely to contain target species. We planned a lower search intensity for these areas. Nearly the entirety of zone 7 was overgrown with a dense carpet of *M. vimineum* or thickets of *Rubus phoenicolasius*, with large areas of *Ailanthus altissima* in the overstory. We did not search this zone for target species. *Primula meadia*, *C. sparganioides*, *D. tricornis*, *H. maximum*, *C. viorna*, *C. hitchcockiana*, *E. bulbosa*, and *L. loeselii* have all been documented within or near Snively Woods (Figure 2). The majority of these occurrences are in the Limestone Oak-Hickory and Rich Red Oak-Sugar Maple forests in zones 3, 5, and 6, with a few other occurrences documented in zones 1, 4, and 8.

After consultation with park staff, we also surveyed Rohrback Woods, a sixth forested area directly across Antietam Creek from the northern portion of Snively Woods.

Survey Methods

From June 2024–June 2025 surveys were conducted by two people walking 2–10 m apart, depending on terrain and sightlines. Due to the size and heterogeneity of the areas to be searched, this project did not employ traditional sampling methods such as measured linear transects or grids. Where possible, the terrain was traversed by walking parallel transects and systematically moving through the area of interest (Nelson 1985). GPS tracks were recorded for each survey session and represent the path of one observer (Figure 5). We tried to visit each woodlot or zone at least twice, once in spring or early summer and then again in the fall. On repeat visits, we shifted our search transits to minimize overlap with areas previously traveled when possible. In some steep areas, there were only a few paths where safe travel was possible. In other areas, the terrain was too steep to access certain locations (within Snively zones 3, 6), or dense non-native vegetation (Snively zone 3, north end of Sherrick Woods, center portion of Union Advance), or large tree falls (West Woods) prevented access.

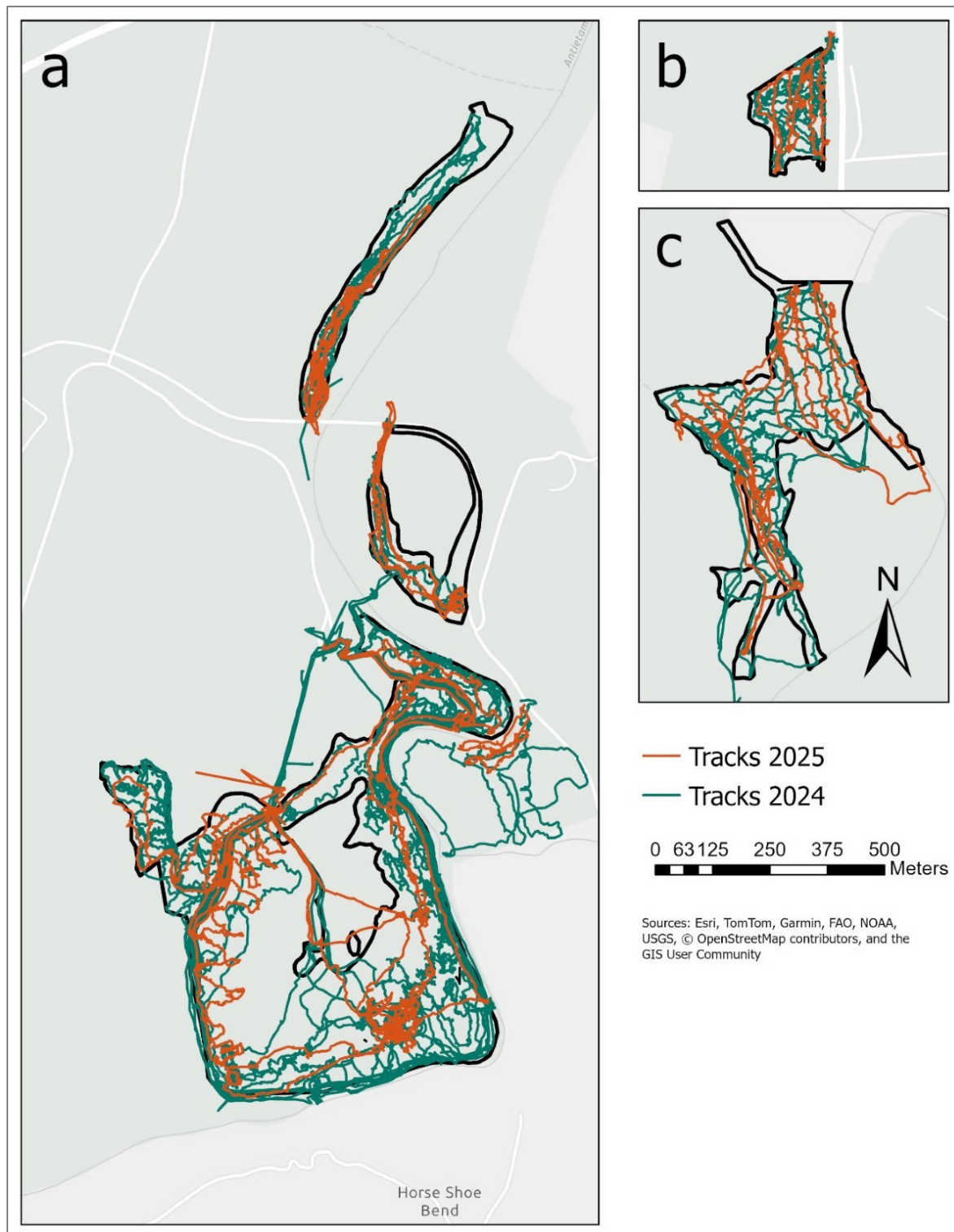


Figure 5. GPS tracks of searches for target RT&E species at ANTI in 2024 and 2025 in (a; top to bottom) Sherrick, Union Advance, and Snavelly Woods, (b) West Woods, and (c) Roulette Woods at ANTI. Each line represents the path of one of a pair of searchers walking 2–10 m apart, depending on terrain and sightlines.

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Occurrences were entered into Survey123 as population categories of 1–20, 21–100, 101–200, or 201–500 individuals with an associated area of <1 m², 1–5 m², 5–10 m², 10–50 m², or 50–100 m². Each occurrence represents the number of individuals estimated to occupy an approximately 100 m² area, but we used the aforementioned categories to provide an estimate of the actual spatial extent of each group of plants encountered. We also recorded information on associated understory and overstory species and attempted to collect phenology data (vegetative, flowering, fruiting) at each point, but the phenology data failed to download correctly and may be lost. At least one photograph was taken at every point entered and is associated with the Survey123 database used.

In 2024, we made 24 trips between June 6 and October 18 and surveyed 57 miles (92 km) over 121 hours. In 2025, we made 14 trips between March 20 and June 20 and surveyed 26 miles (41 km) over 59 hours (Figure 5).

Analysis Methods

We obtained information on soil map units from the Maryland Soil Survey Geographic Database soils data set (Soil Survey Staff 2025), and aspect and slope information from a Digital Elevation Model for Washington County, Maryland (Maryland iMap 2018). Information on the species composition of the overstory vegetation, as determined in the Federal Geographic Data Committee's U.S. National Vegetation Classification database, was provided by park personnel.

We visited the National Archives to scan photographs of the earliest known aerial photography of the area, taken in 1936 and 1938¹. We georeferenced these photographs to present-day (2021) imagery from the National Agriculture Imagery Program (National Agriculture Imagery Program 2023) and delineated polygons of forested area by hand.

We used ArcGIS Pro (ESRI 2025, version 3.5.1) to determine the slope, aspect, soil map unit, and overstory vegetation community for each of the target species occurrences we recorded. We also recorded whether points fell into an area that was forested in 1936–1938 (hereafter referred to as the 1936 forest²). We determined the proportional area occupied by each aspect and slope class, soil map unit, and overstory vegetation type for the entire search area and for the portions of the search area that were forested in 1936 (see Appendix).

We used Fisher's Exact Test in R (R Core Team 2025, version 4.5.1) to compare the actual distribution of all occurrence points among slope and aspect categories, soil map units, forest overstory communities, and 1936 forested area to what would be expected if these points were randomly distributed across the entire search area or the 1936 forested area (see Appendix). When there were significant differences across groups, we conducted pairwise comparisons for each category and used the Holm method to adjust for multiple comparisons. We analyzed all occurrences

¹ **Aerial Photography Index for Washington County, Maryland**, Sheet 5 Photograph AHB 31-82. RG-145-Can Locator, DN2313 (AHF) DN2138 (AHF) <https://catalog.archives.gov/id/117085918>

² **Index to Aerial Photography of Washington County, Maryland 1936** Photographs 7 and 9 RG 114 Can Locator, DN 2516 <https://catalog.archives.gov/search-within/139057524>

together as most species had too few occurrences (<10) or were found in too few locations to make statistically valid generalizations as to factors affecting distributions at the species level. This analysis excluded the two occurrences of *R. strepens* that were recorded in Rohrback Woods, and the one occurrence of *Z. aurea* that was recorded in the landscaping below the Burnside Bridge parking lot, as they were outside of our original survey area.

Results

Species Occurrences and Distributions

We found a total of 326 occurrences of 17 target species (Table 2), including two occurrences of *Matelea obliqua* and one occurrence of *Carex careyana* that were new to the park (Figures 6–10).

Table 2. Target species encountered at Antietam National Battlefield during a survey from June 2024–June 2025. Each occurrence represents a location with 1–500 plants in a 100 m² area.

Species	Roulette	Sherrick	Snively	Union	West Woods	Other ^A	Total
<i>Carex careyana</i> ^B	–	–	1	–	–	–	1
<i>Carex hitchcockiana</i>	–	–	1	–	–	–	1
<i>Carex sparganioides</i>	2	4	26	3	–	–	35
<i>Cubelium concolor</i>	–	51	2	–	–	–	53
<i>Cystopteris bulbifera</i>	–	–	6	–	–	–	6
<i>Delphinium tricorne</i>	–	10	13	–	–	–	23
<i>Heracleum maximum</i>	–	–	5	–	–	–	5
<i>Liparis liliifolia</i>	1	–	–	–	–	–	1
<i>Liparis loeselii</i>	–	–	1	–	–	–	1
<i>Matelea obliqua</i> ^B	–	–	2	–	–	–	2
<i>Physalis virginiana</i>	–	–	6	–	–	–	6
<i>Primula meadia</i>	–	–	1	–	–	–	1
<i>Ribes cynosbati</i>	–	–	5	–	–	–	5
<i>Ruellia strepens</i>	23	14	20	8	–	2	67
<i>Scutellaria nervosa</i>	–	–	–	–	1	–	1
<i>Symphyotrichum shortii</i>	5	38	52	13	–	–	108
<i>Zizia aurea</i>	–	–	–	–	–	1	1
Total	31	117	141	24	1	3	317

^A Two occurrences of *R. strepens* were recorded in Rohrback Woods and one occurrence of *Z. aurea* was recorded in the landscaping below the Burnside Bridge parking lot.

^B *Carex careyana* and *M. obliqua* were not on the original target species list but were encountered during the course of the survey.

Target Species

Asplenium resiliens Kunze: No historical points of *A. resiliens* were provided, and we did not find this species in any of the sites surveyed.

Carex hitchcockiana Dewey: One historical point of *C. hitchcockiana* was provided. We searched for this point on two different occasions but were unable to relocate it. We mapped one population in the park.

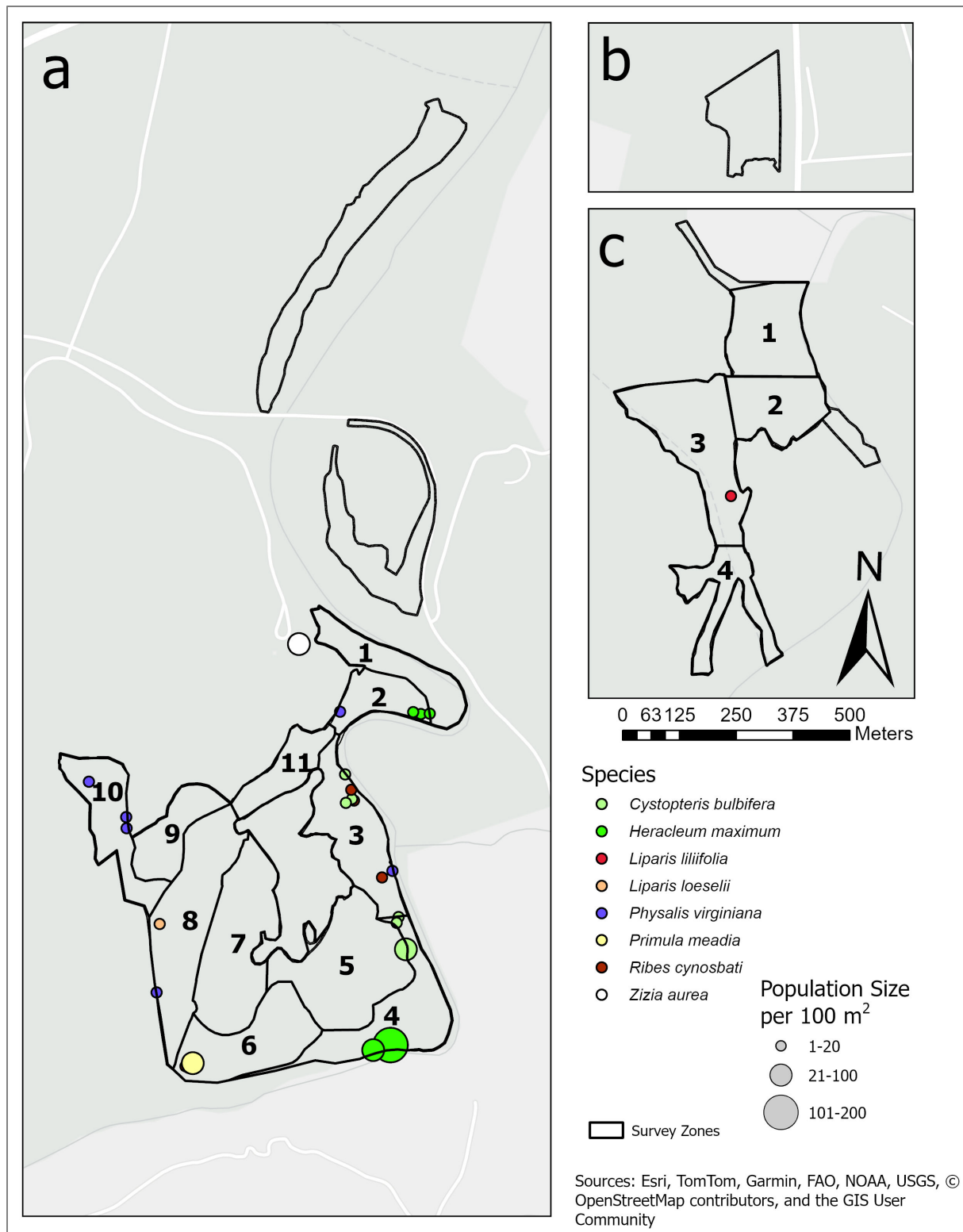


Figure 6. Locations of uncommon target RT&E species (<10 occurrences/species) across (a; top to bottom) Sherrick, Union Advance, and Snaveley Woods, (b) West Woods, and (c) Roulette Woods at ANTI.

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Carex sparganioides Muhl. ex Willd.: Three historical points of *C. sparganioides* in West Woods, Sherrick Woods, and zone 6 of Snavelly Woods were provided. We were able to relocate the populations in Sherrick and Snavelly Woods but could not find the population in West Woods because an extensive deadfall in this area made searching difficult. Initially, we were confusing this species with *C. radiata*, which is more common in the area but has narrower leaves and a longer lower bract. Once we came across a true *C. sparganioides*, we developed a better search image for this species and located 12 additional occurrences in Roulette Woods, three in Sherrick Woods, three in Union Advance Woods, and 26 occurrences in zones 3, 5, 6, 8, 9, and 10 of Snavelly Woods (Figure 7). This species was likely under-surveyed due to our initial difficulties with identification. In some of the rocky areas in Snavelly zones 3, 4, and 5, where we encountered *C. bulbifera*, there was a *Carex* species with narrow leaves and a long lower bract growing among the same rocks. Some of these individuals may be the S1 *C. appalachia*, which, according to Weakley (Weakley and Southeastern Flora Team 2025) typically grows on rocks, while *C. radiata* prefers to grow in soil.

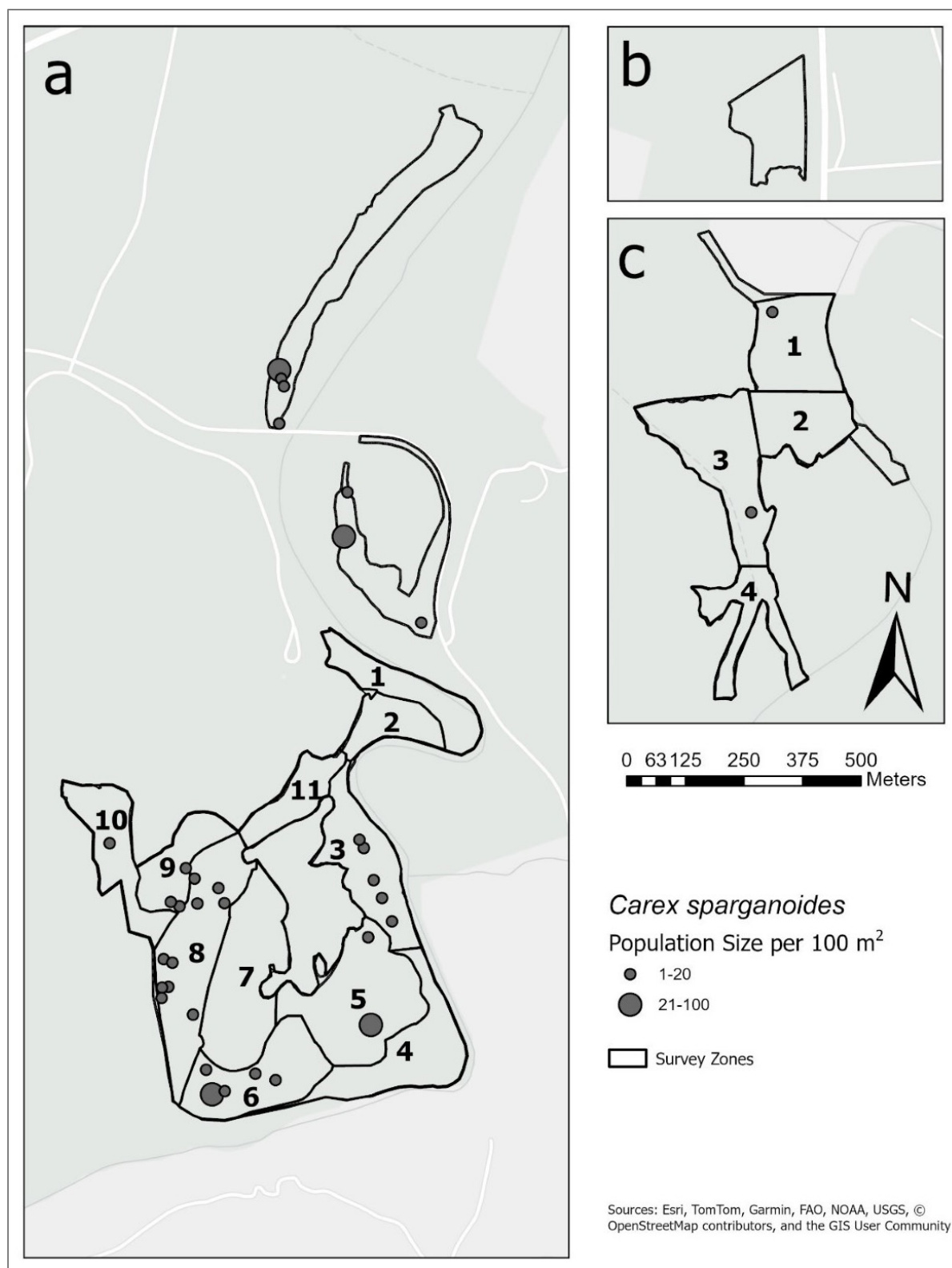


Figure 7. Locations of *Carex sparganoides* across (a; top to bottom) Sherrick, Union Advance, and Snavelly Woods, (b) West Woods, and (c) Roulette Woods at ANTI.

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Castanea dentata (Marshall) Borkh.: No historical points of *C. dentata* were provided and we did not find this species in any of the sites surveyed.

Clematis viorna L.: Although outside our survey area, a historical point of *C. viorna* was provided from the vicinity of the Otto Farmhouse. Out of curiosity, we decided to try and locate this population. On July 19, 2024, we found *Clematis* sp. leaves near the fence on the east side of the farmhouse, but no flowers. We revisited the site on June 12, 2025, hoping to catch it in flower, but could not relocate the plant seen in 2024.

Cubelium concolor (T.F.Forst.) Raf.: We were provided with one historical point for *C. concolor* in Sherrick Woods. This area of Sherrick Woods contains hundreds of *C. concolor* plants spread across 500 m at the south end of this site. We entered 51 *C. concolor* points in Sherrick Woods to show the extent of this population and to call out dense areas and scattered plants. Some of these points may represent areas $<100\text{ m}^2$ as it was difficult to keep track of what had been mapped in this widespread population over multiple visits. Many of these plants are readily visible from the trail. Two other populations of *C. concolor* were located in zone 2 of Snively Woods (Figure 8).

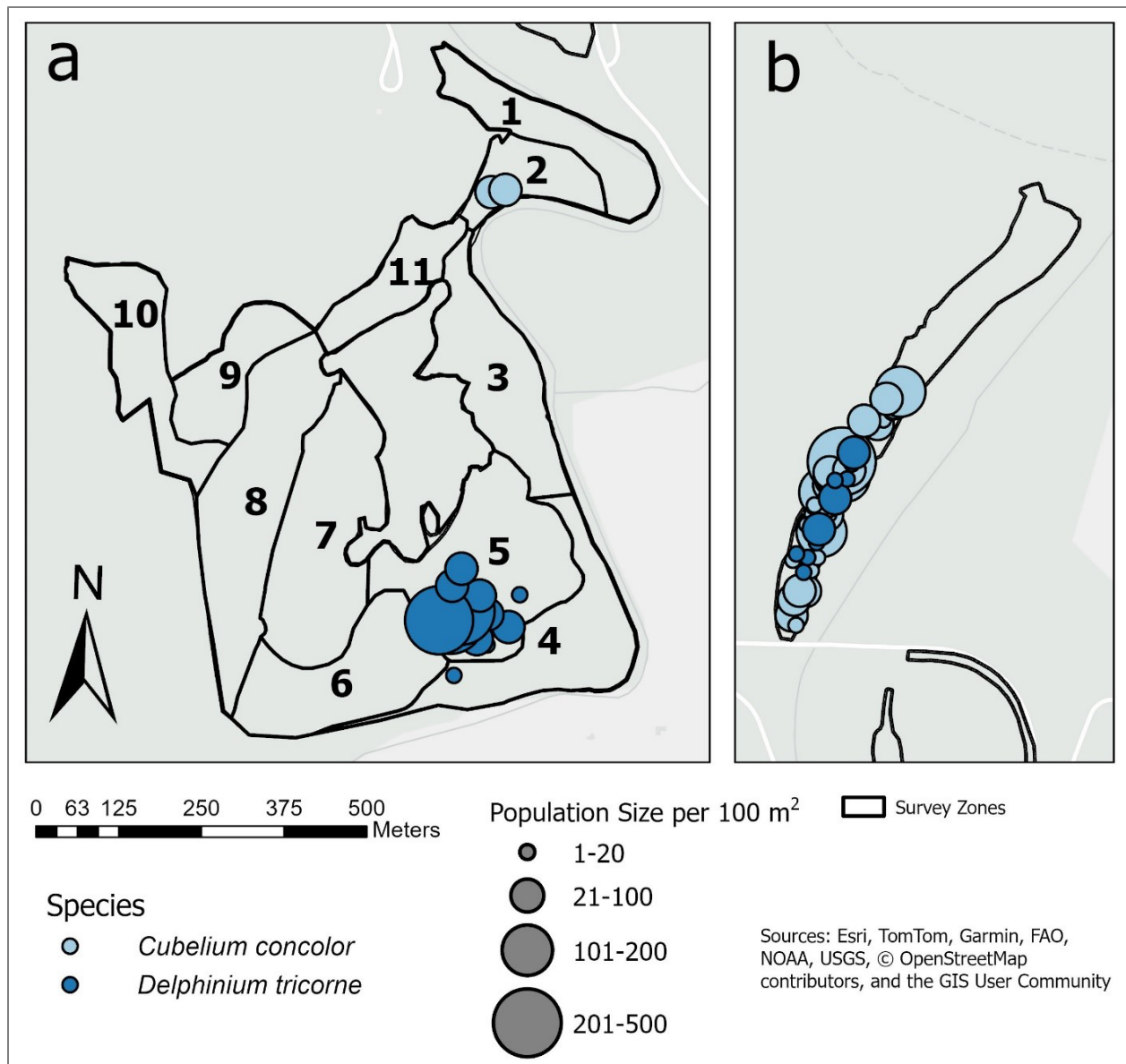


Figure 8. Locations of *Cubelium concolor* and *Delphinium tricorne* across (a) Snavelly Woods and (b) Sherrick Woods at ANTI.

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Cystopteris bulbifera (L.) Bernh.: No historical points of *C. bulbifera* were provided. We found three occurrences of this species in zone 3 of Snavelly Woods and three occurrences at the junction of zones 3, 4, and 5 in Snavelly Woods. One of the occurrences in zone 3 is easily visible from the trail. Another survey conducted at the same time as ours located a large population of *C. bulbifera* (>200 plants) in the area across Antietam Creek from zone 1 of Snavelly Woods (Figure 6).

Delphinium tricorne Michx.: We were provided with two historical *D. tricorne* points, both within zone 5 of Snavelly Woods. These two points mark the edges of the largest population of *D. tricorne* we encountered, consisting of hundreds of plants spreading across this slope. Another large

population of *D. tricornis* exists at Sherrick Woods, where it is spread across about 250 meters of this site. In total, we mapped 13 *D. tricornis* points in Snavely Woods and 10 points in Sherrick Woods (Figure 8). During our initial scouting trips in spring 2024, we found a few occurrences of this species along the Snavely Ford trail in zone 3, but we were not yet equipped with the technology to GPS and log our observations. We resurveyed for these populations in spring 2025, but could not relocate them. We searched Union Advance Woods and West Woods during the flowering time for this species in 2024 and 2025 and did not find *D. tricornis* at these sites. Other *D. tricornis* populations likely exist at Snavely Woods and could exist at Roulette Woods, and future surveys may want to target these areas.

Erigenia bulbosa (Michx.) Nutt.: One historical point of *E. bulbosa* in zone 1 of Snavely Woods was provided. We searched this area on three different occasions in March of 2024 and 2025, but were unable to relocate this population. We did not find this species in any of the sites surveyed.

Heracleum maximum W. Bartram: One historical point of *H. maximum* in zone 4 of Snavely Woods was provided. We relocated this point, which represented a population of hundreds of plants, and entered two points to mark the extent of this population on the floodplain. We also mapped three additional occurrences of this species in zones 1 and 2 of Snavely Woods (Figure 6).

Juglans cinerea L.: Two historical points of *J. cinerea* from West Woods were provided. We searched for these trees on multiple occasions and were unable to find them. There is an extensive deadfall in this section of West Woods, and these trees may be part of that or buried underneath it.

Liparis liliifolia (L.) Rich. ex Lindl. and *Liparis loeselii* (L.) Rich.: Four historical points of *Liparis* sp. were provided from zone 8 of Snavely Woods, and one from the north end of Sherrick Woods. We searched for each of these populations on multiple occasions and were unable to relocate them. We found a new population consisting of six plants of *L. liliifolia* in zone 3 of Roulette Woods and one population of two plants of *Liparis loeselii* in Snavely Woods zone 8 (Figure 6). Given that both these populations were found in areas classified as Successional Old-field Eastern Red-cedar Forest, and a known habitat for *L. loeselii* is mid-successional cedar forests (Matlack 2004), an intensive search of the cedar stand between Snavely Woods zones 9 and 10 for these orchids may be warranted.

Monarda clinopodia L.: No historical points of *M. clinopodia* were provided, and we did not find this species in any of the sites surveyed.

Physalis virginiana P. Miller: No historical points of *P. virginiana* were provided. This species is difficult to differentiate from other Solanaceae/*Physalis* species when not in fruit. According to the Maryland Natural Heritage Program “[m]any MD records in collections are *P. virginiana* P. Miller var. *subglabrata* (Mackenzie & Bush) Waterfall = *P. longifolia* Nuttall var. *subglabrata* (Mackenzie & Bush) Cronquist, a common species of dry woods, fields, gardens and waste places” and “[d]etermining the correct rank and distribution of this species requires substantial field and herbarium work” (Maryland Natural Heritage Program 2021). We were able to positively identify 6 populations of this plant at Snavely Woods using the characteristic of “fruiting calyx 5-angled,

indented at base” for *P. virginiana*, as opposed to “fruiting calyx subterete, with 10 ribs, not indented at base” for *P. longifolia* var. *subglabarata* (Weakley and Southeastern Flora Team 2025). We encountered three *P. virginiana* populations in Snavelly Woods zone 10, with some of these close to the trail and at risk of being mowed. Additional *P. virginiana* were identified in Snavelly Woods zones 2, 3, and 8 (Figure 6). We also found potential populations in Sherrick and Union Woods, but the young ages of these plants made conclusive identification difficult. We revisited some of these plants several times, but never encountered them in flower or fruit.

Primula meadia (L.) A. R. Mast & Reveal: One historical point of *P. meadia* from the west side of zone 6 in Snavelly Woods was provided. We relocated this population of about 25 plants in this same location. We did not find this species in any of the other survey areas (Figure 6).

Ribes cynosbati L.: No historical points of *R. cynosbati* were provided. We located three occurrences of this species in Snavelly Woods zone 3 and two occurrences in Snavelly Woods zone 6 (Figure 6).

Ruellia strepens L.: No historical points of *R. strepens* were provided. This was one of the most abundant target plant species. We recorded 67 populations of this species: 23 populations in Roulette Woods, 22 populations in zones 1–6 of Snavelly Woods, 14 populations in Sherrick Woods, and 8 populations in Union Advance Woods. We also found two populations in the wooded area on the other side of Antietam Creek from Snavelly Woods (Figure 9). In most locations, the *R. strepens* populations at ANTI are sparse, with only a few plants in each area. The densest population is in zone 3 of Roulette Woods, with a widespread population of *R. strepens* in the central area of this zone. Some of these plants are growing immediately adjacent to the trail just north of where it crosses the creek and are being mowed as part of the trail maintenance (we witnessed this on one occasion). The *R. strepens* population along this trail is also mixed with another *Ruellia* species, which we were unable to conclusively identify. This is probably the more common *R. caroliniensis*, but the population should be checked when in flower to rule out the highly state rare *R. humilis*. Other dense populations of *R. strepens* are at the west side of Union Advance Woods, where it is growing adjacent to and into the neighboring pasture area, and at the top end of Snavelly Woods zone 1, where it is growing along the trail between the parking area and Burnside Bridge. There are also a few dense pockets of *R. strepens* at Sherrick Woods where it is growing with *C. concolor*.

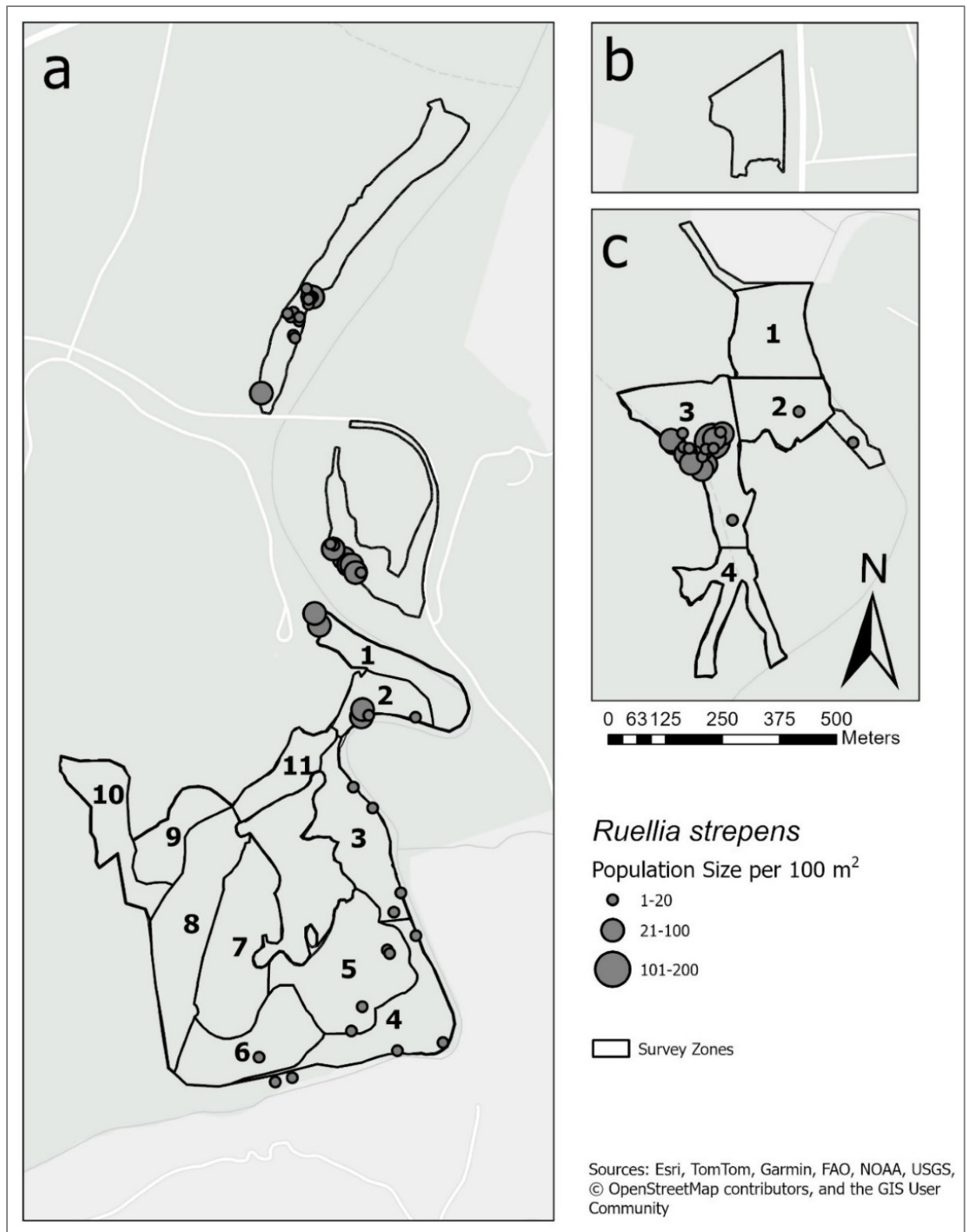


Figure 9. Locations of *Ruellia strepens* across (a; top to bottom) Sherrick, Union Advance, and Snavelly Woods, (b) West Woods, and (c) Roulette Woods at ANTI.

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Scutellaria incana Biehler: One historical point of *S. incana* was provided. Although this point was across the stream from Roulette Woods and technically out of our search area, we looked for it on June 30, 2025, when it was likely to be in flower and were unable to relocate it.

Scutellaria nervosa Pursh: One historical point of *S. nervosa* was provided. We looked for this point several times, but it is under an extensive deadfall and is likely buried. We documented another population in the park.

Symphyotrichum shortii (Lindl.) G. L. Nesom: No historical points of *S. shortii* were provided. This was the most abundant species on the target list with 108 occurrences, fitting with the description by the Maryland Natural Heritage Program (2021) of being “[n]arrowly distributed along the Potomac River (and tributaries) in w. MD but often locally abundant”. Like *R. strepens*, most occurrences of this species consist of a few individuals. Dense populations were rare. Some of the largest populations are in the central area of Sherrick Woods, the south end of Union Advance Woods near the 11th Connecticut Infantry Regiment monument, the northern sections of zones 1 and 2 in Snavelly Woods, and at the southwest corner of the Snavelly Ford trail in zones 6 and 8 (Figure 10).

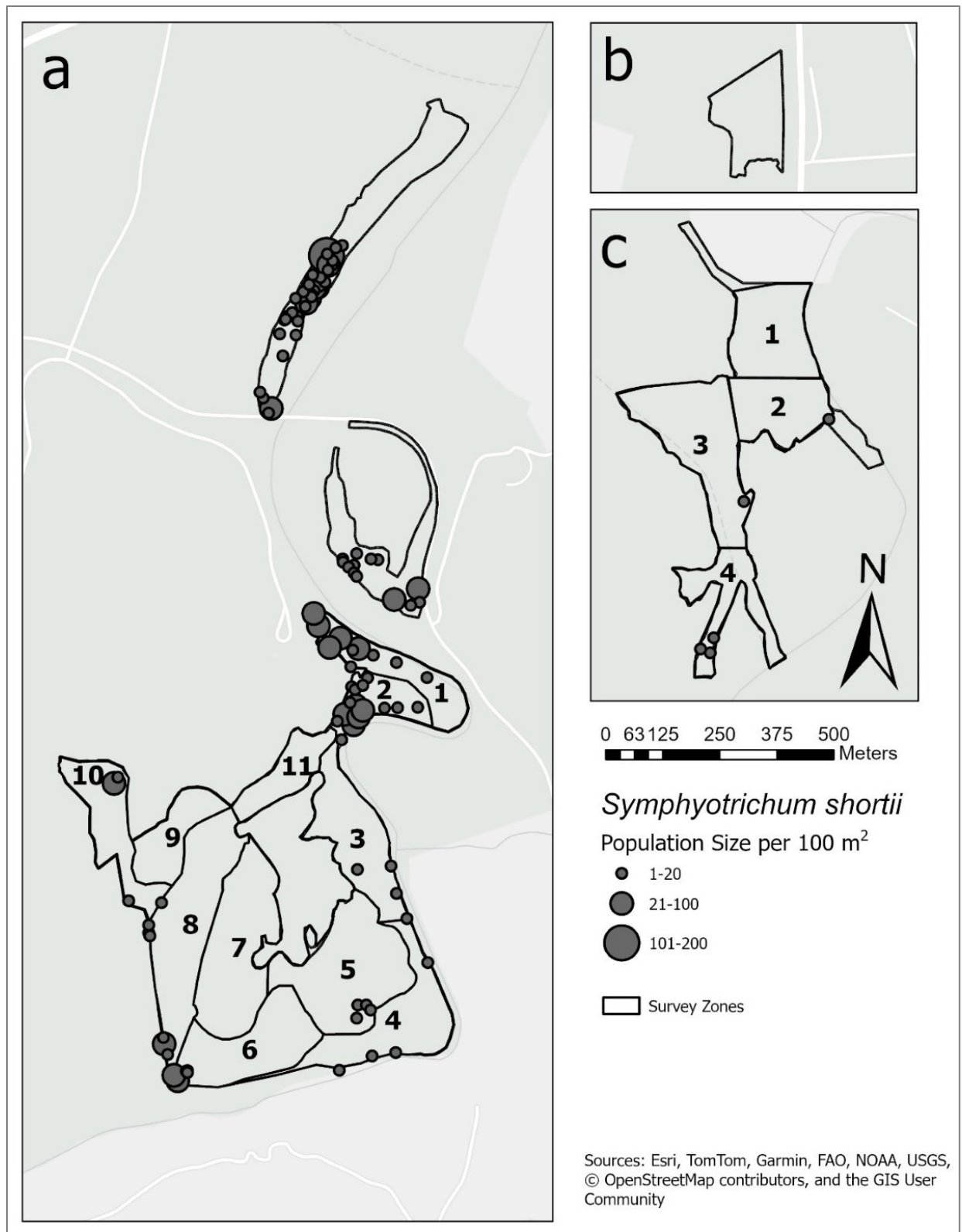


Figure 10. Locations of *Symphyotrichum shortii* across (a; top to bottom) Sherrick, Union Advance, and Snively Woods, (b) West Woods, and (c) Roulette Woods at ANTI.

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Zizia aurea (L.) W. D. J. Koch: No historical points of *Z. aurea* were provided. We found this species in the landscaping below the Snavely Ford parking lot, where it was included in a seed mix that was applied to the area (Figure 6).

New Species

In the course of this survey, two species were added to the list of RT&E species known at ANTI. With guidance from NPS Biologist Sarah Brown, we located one population of *C. careyana* Torrey (S1, G4). We also documented two plants of *M. obliqua* (Jacquin) (S1, G4).

Forest Stand Descriptions

Snavely Woods

Snavely Woods was the largest and most diverse of the forested areas surveyed. Nearly half (44%) of the points entered were in Snavely Woods.

Five areas have particularly high concentrations of target species:

1. Zone 1 along the trail to Burnside Bridge and in the forest downslope from the trail has large populations of *S. shortii* and *R. strepens* (Figures 9 and 10).
2. Zone 2 at the bend in Antietam Creek has several substantial populations of *S. shortii* and *R. strepens*, along with two groups of *C. concolor* (Figures 8–10). This is the only location where we found *C. concolor* in Snavely Woods. Immediately south of this section is an area that is blocked at the bottom by *Rosa multiflora* and is too steep at the top to enter. There may be more instances of target species in this section.
3. Zone 3, along the east side of these woods, is home to the only populations of *C. bulbifera* we encountered. *Ribes cynosbati*, *C. sparganioides*, *R. strepens*, and *S. shortii* are also present in this section (Figure 6). One individual of *C. bulbifera* are conspicuous from the trail. The center part of this section is particularly steep and may have other populations of target species we missed due to not being able to access this area safely.
4. The south end of Snavely Woods has a dense population of *H. maximum* on the floodplain at the edge of the trail in zone 4. The hill itself is covered with hundreds of *D. tricornis* mixed with *C. sparganioides*, *R. strepens*, and *S. shortii* (Figures 6–10). Areas to the northeast and southwest of this section were very steep and may have other populations of target species that we were unable to access.
5. Zone 6 at the southwest corner of Snavely Woods is home to a population of >20 *P. meadia* up among the rocks, an extensive area of *S. shortii* along the trail, and the only other population of *R. cynosbati* we encountered (Figures 6 and 10).

The west side of Snavely Woods has fewer occurrences of target species than areas to the east and south. Notable occurrences in the section are the only populations of *L. loeselii* we encountered (zone 8), and several populations of *P. virginiana* (zones 8 and 10). *Carex sparganioides* and *S. shortii* are scattered throughout zones 8, 9, and 10 (Figures 6, 7, and 10).

Union Advance Woods

Ridge and Valley Limestone Oak-Hickory Forest dominates the north end of this forest stand (Figures 11a and 12a, see also Figures 7, 9, and 10). There was a high concentration of spring ephemerals in this section, and we searched intensively for target species but only found a few occurrences of *C. sparganioides*. The central area of these woods has a large population of *R. strepens* mixed with *S. shortii* that extends from the edge of the pasture up into the steeper rocks as you move from north to south through this section. The southeast corner of Union Advance Woods also had sizeable populations of spring ephemerals and hosted several patches of *S. shortii* and one population of *C. sparganioides*. We also found a few scattered individuals of *S. shortii* along the trail. In total, we found 24 occurrences of target species in Union Advance Woods (Figures 7, 9 and 10).

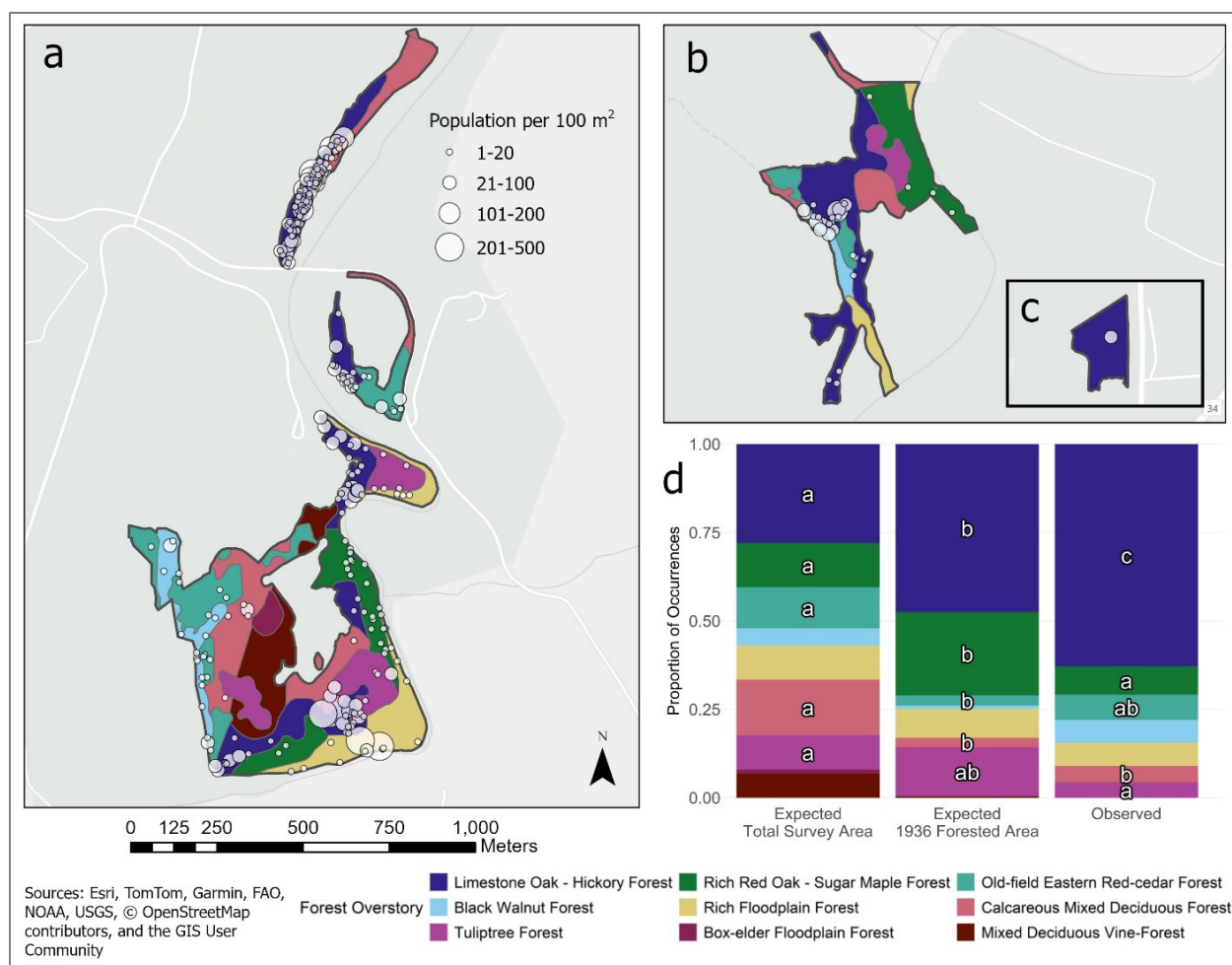


Figure 11. Locations of target RT&E species with respect to forest overstory vegetation community in (a) Snavelly, Union Advance, and Sherrick Woods, (b) Roulette Woods and (c) West Woods. (d) Comparison of the observed distribution of points by forest overstory type with the distribution expected if points were spread randomly across the entire survey area or the area forested in 1936 showing that RT&E species at ANTI are more frequently encountered in Limestone Oak-Hickory Forest than would be expected by chance in either area. Within each community type, groupings with the same letter are not significantly different. Significance notations are only shown for groups comprising >10% of the total survey area.

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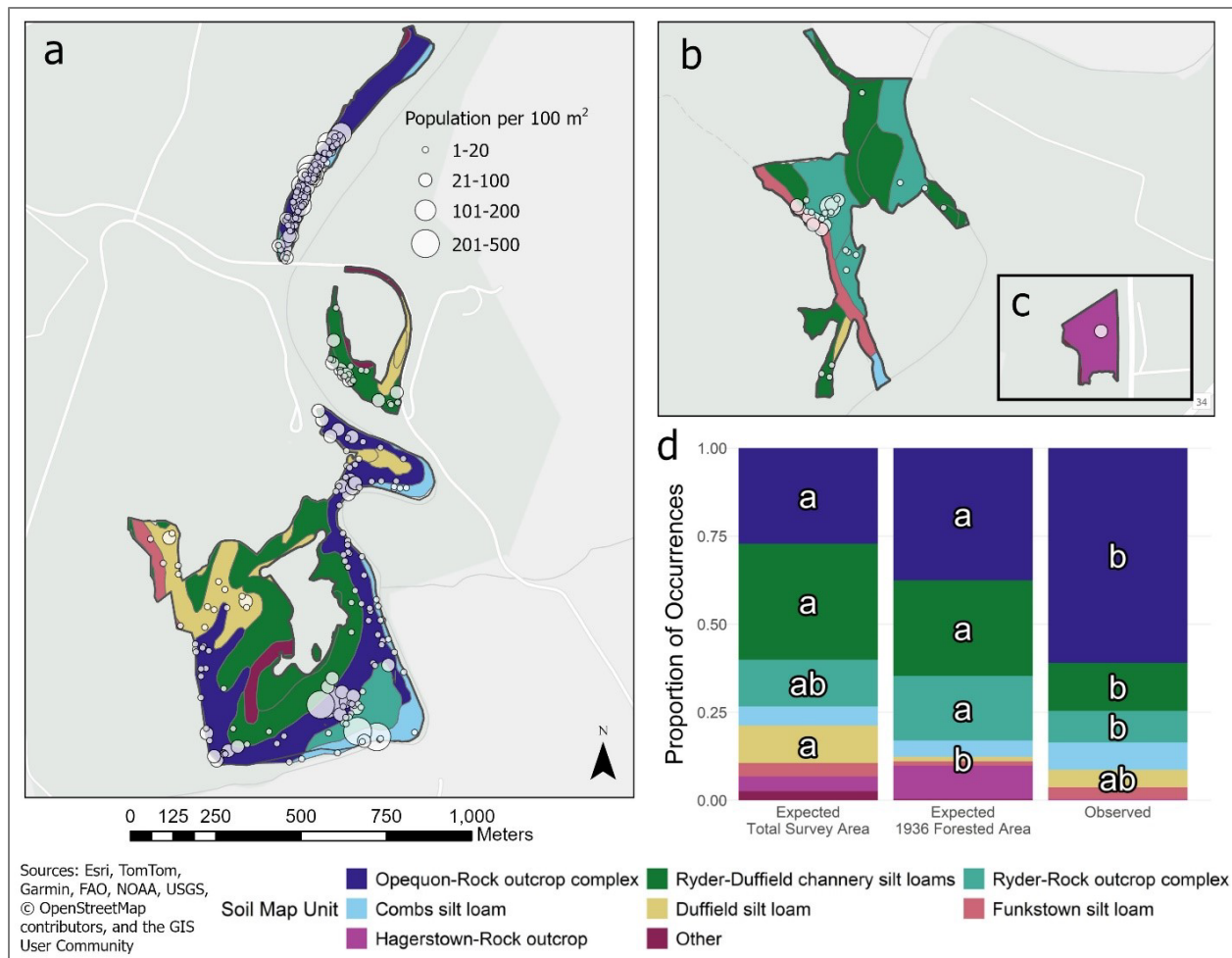


Figure 12. Locations of target RT&E species with respect to Soil Map Unit in (a) Snavelly, Union Advance, and Sherrick Woods, (b) Roulette Woods, and (c) West Woods. (d) Comparison of the observed distribution of points by Soil Map Unit with the distribution expected if points were spread randomly across the entire survey area or the area forested in 1936 showing that RT&E species at ANTI are more frequently encountered in Opequon-Rock Outcrop Complex Soils than would be expected by chance in either area. Within each soil type, groupings with the same letter are not significantly different. Significance notations are only shown for groups comprising >10% of the total survey area.

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Sherrick Woods

All of the 122 target species locations at Sherrick Woods were concentrated at the south end of this forest stand. This area is underlain by steep Opequon-Rock outcrop complex soils with a Ridge and Valley Limestone Oak-Hickory Forest in the overstory (Figures 11a and 12a, see also Figures 7, 9, and 10). This area hosts a large population of *C. concolor* that was so extensive it was difficult to map (51 points). Points that were recorded are intended to convey the extent of the population, the differences in density from area to area, and also capture the areas that only had scattered individuals (Figure 8). A detailed survey of this site was beyond our capacity, given the other areas we were tasked with surveying. This entire area is very steep, and there were spots, particularly about halfway up the hill, where options for safe travel were limited. These mid-slope areas were searched less

thoroughly than the lower sections that can be seen from the trail and the areas toward the top of the slope that could be accessed from deer trails that ran across the top of these woods. There are also several patches of *Rosa multiflora* in this section that prevented thorough searching. The south section of Sherrick Woods also supports populations of *C. sparganioides* (Figure 7), *D. tricornis* (Figure 8), *R. strepens* (Figure 9), and *S. shortii* (Figure 10).

The northern end of this forest stand, although underlain by the same Opequon-Rock outcrop complex soils, contains more early successional vegetation. This area contains some areas of Ridge and Valley Limestone Oak-Hickory Forest, but has a more open canopy, and some sections are heavily invaded by *R. multiflora* and other invasive shrubs. We conducted several searches for the *Liparis* sp. noted in this northern section, but we did not find it or any of the other target species in this area.

Roulette Woods

We found 41 occurrences of target species spread across several different areas at Roulette Woods. Zone 1 of Roulette Woods is characterized by Ridge and Valley Limestone Oak-Hickory Forest and Central Appalachian Rich Red Oak-Sugar Maple Forest and contains many large, mature *Quercus* sp., particularly toward the north and west edges (Figures 11b and 12b). While there are invasive species in the understory, *M. vimineum* in particular was much less dense than in zone 2 to the south. We expected this area to have populations of several target species, but despite multiple searches, we only located one population of *C. sparganioides* in this section (Figure 7). We were unable to search this area in early spring of 2025, so there may be *D. tricornis* that we missed. We were also unable to access the steep eastern edge of this zone.

Zone 3 was the other high-quality area of Roulette Woods with overstory communities of Ridge and Valley Limestone Oak-Hickory Forest, Successional Old-field Eastern Red-cedar Forest, and Successional Black Walnut Forest (Figures 11b and 12b). An extensive patch of *R. strepens* extends along the trail north of the creek crossing and up into the woods to the east (Figure 9). This population is mixed with another *Ruellia* species that is smaller with more pubescent leaves and thinner calyx lobes than *R. strepens*. This is likely *R. caroliniensis*, but the population should be checked when in flower to rule out the highly state rare *R. humilis*.

Other populations of target species are scattered through other areas of this wooded area. We found a small population of *R. strepens* in zone 2 mixed in with *M. vimineum* and *Verbesina alternifolia* and a few individuals of *S. shortii* in zones 2, 3, and 4 (Figures 9 and 10). The red-cedar forest in zone 3 is also home to the only population of *L. liliifolia* we found during our survey (Figure 6). We also found a pocket of relatively high-quality forest, adjacent to zone 2, that was not included in our original map of Roulette Woods. In trying to access the floodplain adjacent to zone 1 we attempted an approach from the south. Although unsuccessful due to erosion and multiple downed trees, we found a pocket of forest that had an abundance of spring ephemerals and low density of invasive understory species. This area contained *R. strepens* and *S. shortii* (Figures 9 and 10), along with the only individuals of *Galearis spectabilis* and *Ellisia nyctelea* we encountered during our survey. This area

warrants further exploration as it has a similar aspect and slope to the areas of Snavelly and Sherrick Woods that have a high density of RT&E target species, and it was forested in 1936.

West Woods

West Woods is dominated by the same Ridge and Valley Limestone Oak-Hickory Forest that characterizes areas in Snavelly and Sherrick Woods with high abundances of target species (Figure 11c). However, despite searching this area four different times, we only found one population of *S. nervosa* (Figure 6). Two locations for *J. cinerea* were provided for this woodlot (Figure 3), but they are in an area that is now an extensive deadfall that likely contains or has crushed the previously mapped *J. cinerea*.

Rohrback Woods

At the request of park biologists, we added the area across Antietam Creek from Snavelly Woods to our search area and visited this area in October of 2024 and April of 2025. We did not have the time to survey this area thoroughly. The section of steep slope adjacent to the river has good quality habitat with minimal invasive species and a high concentration of ephemerals in the spring. This was the only place in the park where we observed *Erythronium americanum*, and another researcher found a population of >200 *C. bulbifera* later in the spring of 2025 (Sarah Brown, NPS, personal communication). We located one occurrence of *R. strepens* along the trail near the parking area and another at the edge of the creek along the southern property line (not shown).

Patterns of Target Species Distribution

Comparison of the distribution of target species occurrences among slope and aspect categories, soil map units, forest overstory communities, and 1936 forested area to the proportions of these categories in the total modern-day search area and the 1936 forested area showed that the distribution of target species, as a group, was different from what would be expected were these points distributed randomly across the landscape.

1936 Forested Area

Target species were much more likely to be found in areas that were forested in 1936 and likely remained forested since then ($p < 0.001$; Figure 13d; see Appendix). Although 50% of the search area was forested in 1936, 78% of the recorded points fell within these areas. *Ribes cynosbati*, *C. bulbifera*, and *P. meadia*, found infrequently (1–6 occurrences per species), never occurred outside of historically forested areas. For *D. tricornis*, only 1 out of 23 occurrences was outside the historically forested area, and most other species also primarily occurred within the 1936 forested zones. *Physalis virginiana*, *C. sparganioides*, *S. shortii*, and *R. strepens* were the most likely to occur outside these areas, with 50%, 46%, 29%, and 22% of their occurrences, respectively, found outside the historically forested regions.

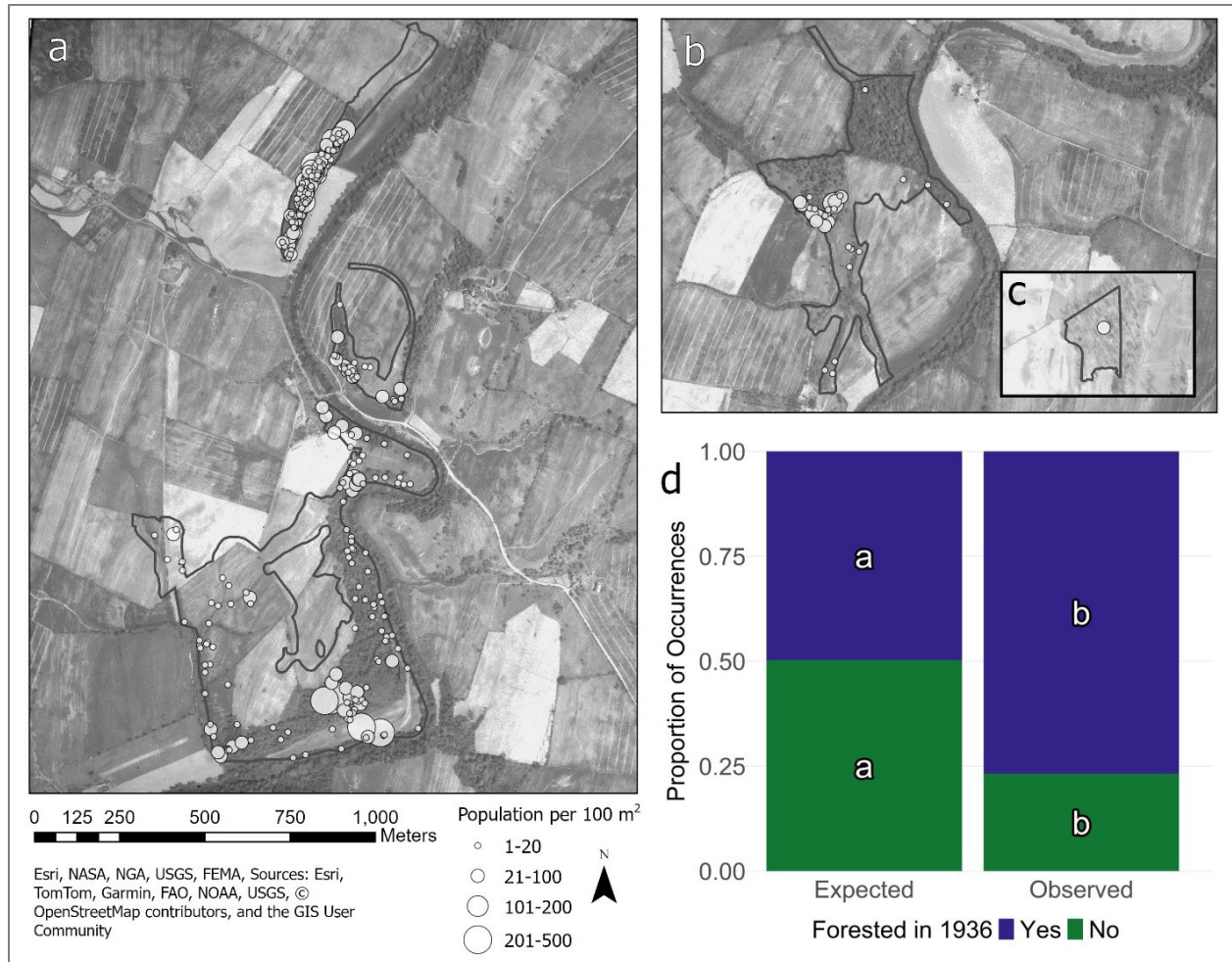


Figure 13. Locations of target RT&E species with respect to areas forested in 1936 in (a) Snavely, Union Advance, and Sherrick Woods, (b) Roulette Woods and (c) West Woods. (d) Comparison of the observed distribution of points by 1936 forested area with the distribution expected if points were spread randomly across the entire survey area showing that RT&E species at ANTI are more frequently encountered in areas that were forested in 1936 than would be expected by chance.

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Slope and Aspect

The observed distribution of points across the slope categories was similar to that of the 1936 forested areas ($p > 0.05$; see Appendix), suggesting that continuously forested areas play a large part in determining where these plants are found at ANTI (Figure 14). Nearly 50% of occurrences were recorded on steep slopes ($>20\%$) because these slopes make up nearly 40% of the area that was forested in 1936 (Figure 14). Likewise, while there was a significant difference between the distribution of aspect categories within the total survey area and the actual distribution of points ($p = 0.002$) and between the actual distribution of points and the portion of area occupied by each aspect category in the 1936 forested area ($p < 0.006$), post-hoc tests controlled for multiple comparisons showed only slightly fewer points on northeast facing slopes (22.5° – 67.5°) than expected based on the 1936 forested area (see Appendix). The majority of plants were found on east and southeast

facing slopes (55% of occurrences) because these slopes make up 41% and 50% of the area in the total survey area and the 1936 forested survey area, respectively (Figure 15).

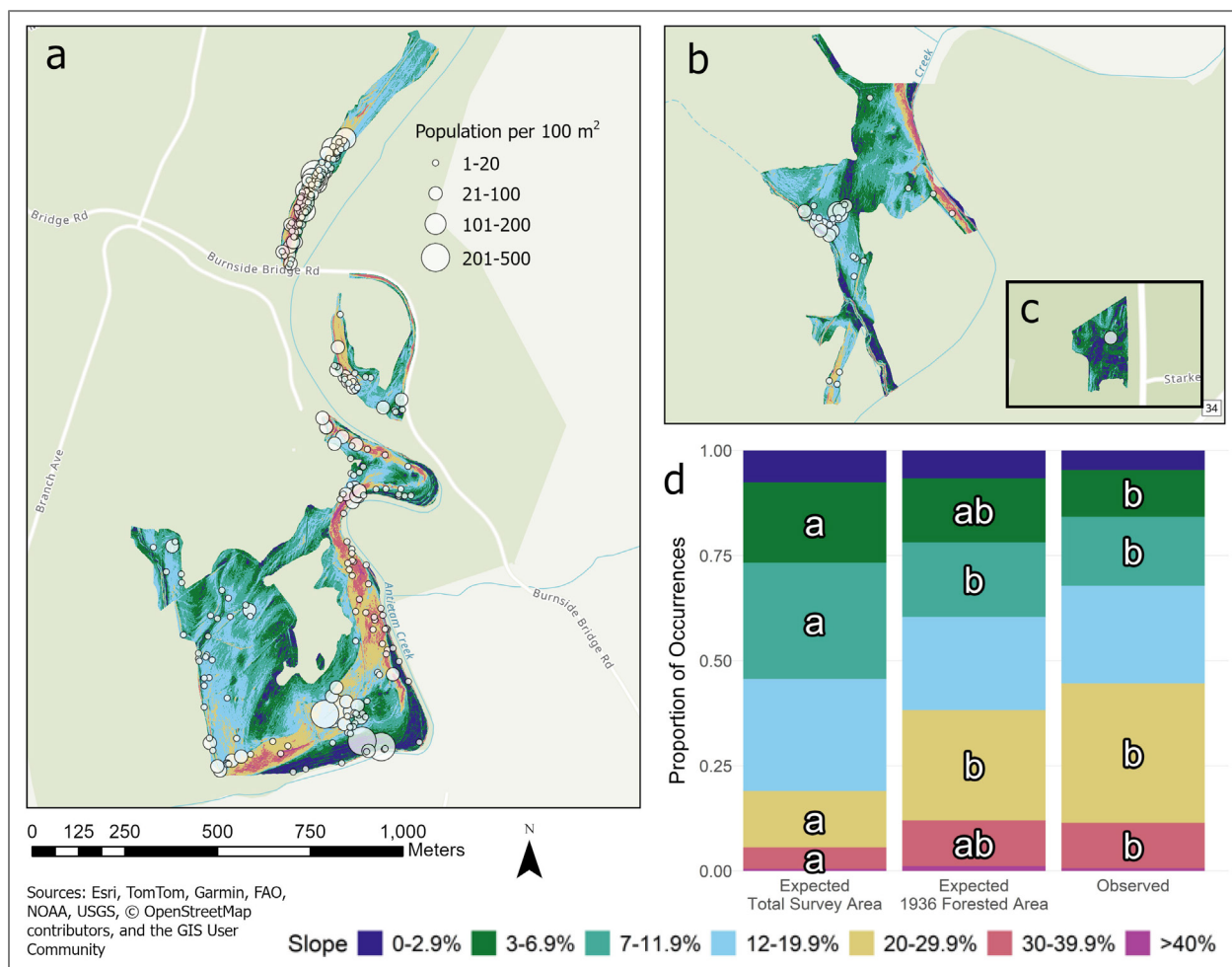


Figure 14. Locations of target RT&E species with respect to slope in (a) Snavelly, Union Advance, and Sherrick Woods, (b) Roulette Woods and (c) West Woods. (d) Comparison of the observed distribution of points by slope class with the distribution expected if points were spread randomly across the entire survey area or the area forested in 1936 showing that the distribution of RT&E species at ANTI is similar to the distribution of slope categories across the areas that were forested in 1936.

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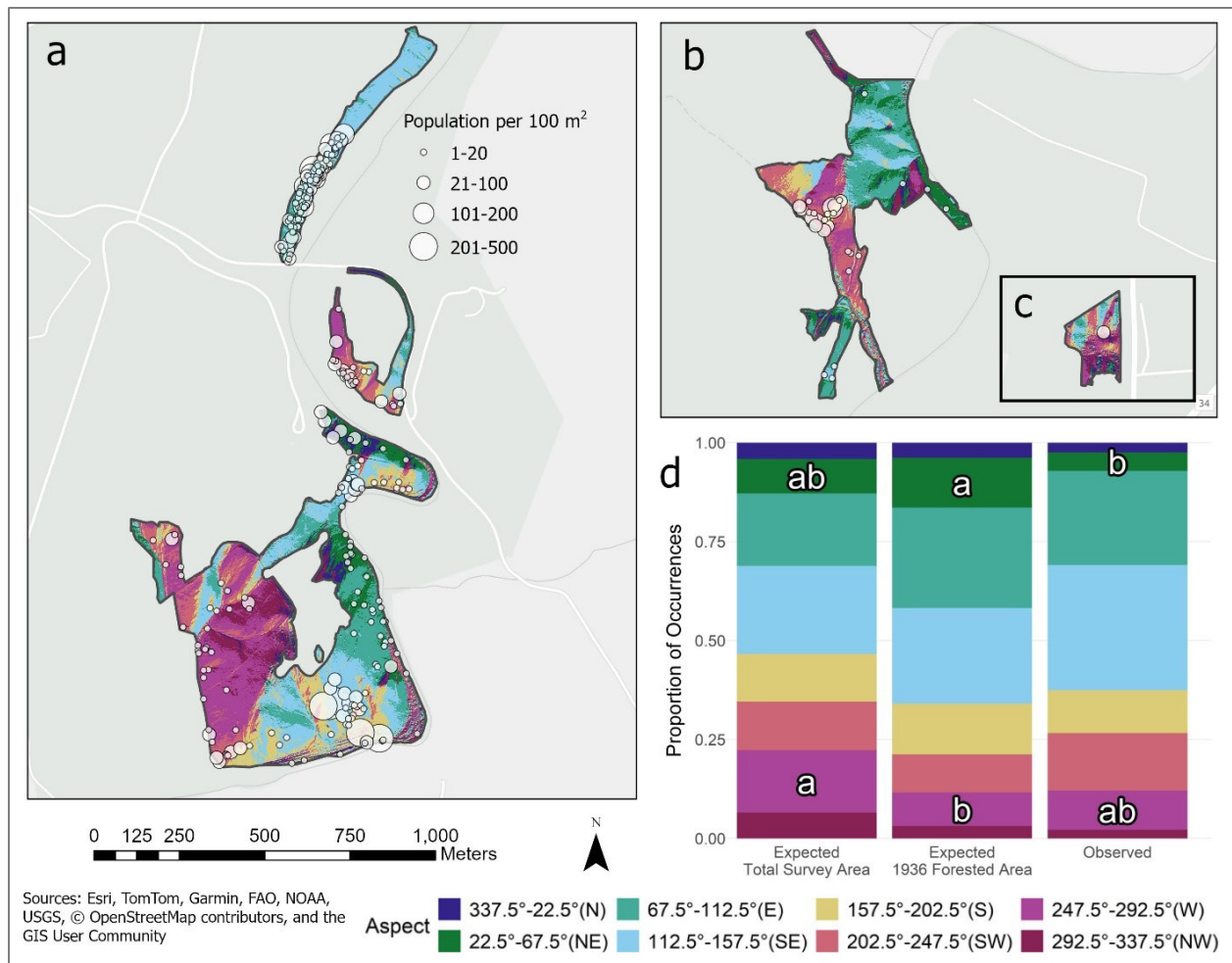


Figure 15. Locations of target RT&E species with respect to aspect in (a) Snavely, Union Advance, and Sherrick Woods, (b) Roulette Woods, and (c) West Woods. (d) Comparison of the observed distribution of points by aspect class with the distribution expected if points were spread randomly across the entire survey area or the area forested in 1936 showing that the distribution of RT&E species at ANTI is largely similar to the distribution of aspect categories across the areas that were forested in 1936.

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Soils and Vegetation

Occurrences of RT&E species were significantly influenced by soil type and overstory vegetation community ($p < 0.001$ for both). RT&E plant species are more likely to occur on Opequon-Rock outcrop soils and in association with Limestone Oak-Hickory Forests than is predicted by the proportional area of these classes across the entire search area or the 1936 forested area (Figures 11 and 12; see Appendix). Sixty-seven percent of target species occurrences were on Opequon soil, and 71% were in Limestone Oak-Hickory Forest, despite them making up 26% and 28% respectively, of the total search area and 38% and 49%, respectively, of the 1936 forested area.

Conclusions

Factors Affecting RT&E Species Distribution at ANTI

Land Use History

The intersection of land use history and geology plays an important role in shaping the distribution of RT&E species at ANTI. Located in the Great Valley section of the Ridge and Valley physiographic province, ANTI and the surrounding lands sits atop carbonate soil, which is known for being particularly fertile (Bowman 1911). In his *History of Washington County, Maryland*, Williams (1906) writes that in the Hagerstown Valley “[t]he soil of nearly the whole of this valley is limestone of the best and most productive character” and that “[i]n the main valley the scenery is that of a rich agricultural country displaying fertile fields, well cultivated farms, large barns and comfortable farm houses, with landscapes of magnificent beauty, having always the blue mountains for a background.” As with other areas in the northeastern United States, the limestone rock outcrops at ANTI, which are typically considered unsuitable for farming, were some of the only areas left undisturbed. Orurand’s 1899 Map of the Battlefield of Antietam (United States War Department 1908) shows forested areas in the same locations and shapes as those seen in the 1936–1938 aerial photographs, further suggesting that these areas were never cleared for agricultural purposes. It is likely that, before this area was settled, many of these plant species were more widespread, but agricultural conversion of the valley bottom has restricted them to these last areas of outcrop refugia (Houston et al. 2025).

Subsequent reversion of agricultural areas to forest does not guarantee that the species that once inhabited those spaces will be able to return (Foster et al. 2003). Much of the eastern United States has seen an increase in forest cover since the abandonment of small-scale farms began in the 1850s (Foster 1992; Steyaert and Knox 2008), with 42% of the area of Washington County classified as forested in 2018 (Minnemeyer et al. 2022). However, these secondary forests differ in composition from the primary forest they are replacing (Cramer et al. 2008; Dupouey et al. 2002; Foster et al. 2003; Glitzenstein et al. 1990). Intensive agriculture involves disruption to soil structure, chemistry, and microbial communities, and these effects can last for centuries, making post-agricultural land unsuitable habitat for many forest plant species (Foster et al. 2003; Parkhurst et al. 2021). As succession proceeds, competition from disturbance-adapted invasive species and depletion of seed banks can also put some native forest species at a disadvantage, leaving many secondary forests with lower richness and different species composition compared to primary forests (Cramer et al. 2008; Dupouey et al. 2002; Glitzenstein et al. 1990; Isbell et al. 2019; Orwig and Abrams 1994).

Dispersal Ability

Recovery of native species in secondary forests may also be limited by their dispersal capabilities (Donohue et al. 2003; Peterken and Game 1984; Singleton et al. 2001). Many herbaceous species of stable, mesophytic forests often have low seed production, low germination rates, and rely on ants or gravity for seed dispersal (Bellemare et al. 2002). These traits, in combination with the fragmented nature of forest patches in an agriculturally dominated landscape like that of ANTI, reduce the chance that many of these species would be able to move among primary forest patches or recruit

into secondary forest patches, even if the edaphic conditions were suitable (Peterken and Game 1984).

This dispersal limitation could play a role in the distribution patterns seen at ANTI for several of the target RT&E species for this project. With its red fruit, *H. canadensis* can be attractive to birds and is reported to be dispersed by turkeys, songbirds, mice, and arthropods. However, successful establishment from seed is low, and the majority of reproduction occurs via clonal growth (Dodds 2024). These reproductive characteristics of *H. canadensis* create a pattern of sometimes locally dense patches but infrequent occurrences across the landscape (Houston et al. 2025). Likewise, at ANTI, the distributions of *D. tricornis*, *C. concolor*, and to a lesser degree, *R. strepens*, are also characterized by dense but infrequent occurrences. These species are gravity-dispersed from follicles or capsules (Johnson 2022; Little 2025; Warnock 2025), making long-distance dispersal improbable. Although the ballistic nature of *C. concolor* and *R. strepens* dispersal can launch seeds several meters away from the parent plant (Hesse-Withbroe and Whitaker 2024; Johnson 2022), most seedlings would be expected to recruit in the immediate vicinity of parent plants. The clonal growth of *C. concolor* could reinforce this pattern (Johnson 2022). Conversely, *P. virginiana* and *S. shortii* likely have dispersal strategies that could account for their wider distribution at ANTI and their greater presence in areas that were not forested in 1936. *Physalis virginiana* produces a berry that is enclosed in a lantern-like calyx and is presumably dispersed via endozoochory, a seed dispersal mechanism in which the seed is consumed and excreted by an animal (Rojas et al. 2022; Valenta et al. 2020), allowing for more widespread distribution than the previously mentioned species. The presence of pappus on *S. shortii* achenes (Valenta et al. 2020) suggests that they may be wind-dispersed, again allowing for greater dispersal distances than other RT&E species at ANTI. These disparities in dispersal ability, combined with the isolation of the different remnant forest patches at ANTI, may explain why of the 19 RT&E species we encountered, only *C. sparganioides*, *R. strepens*, and *S. shortii* were found in more than two of the five forest remnants we searched, and why West Woods, Union Advance Woods, and Roulette Woods support only a few RT&E species despite containing what seems to be suitable habitat (Brunet 1993; Peterken and Game 1984).

Local Site Conditions

Local site conditions of remnant forest patches may also contribute to the ability of an area to support RT&E species. West Woods has the same Limestone Oak-Hickory overstory and similar rock outcrop geology as areas of ANTI that had high occurrences of target species, and also has a low presence of invasive species in the understory like *M. vimineum*. However, despite several intense searches, we only located one population of target species in this area. The history of this site as a managed woodlot may be affecting its ability to host RT&E species. In a study of forested areas of the Cary Arboretum in New York, Glitzenstein et al. (1990) found that sites that were likely pastured as opposed to cultivated had a forest overstory community more similar to that of an undisturbed forest, but that the understory vegetation community composition was still substantially altered. Other studies have found that selective tree harvest has minimal effect on the population size, growth, or reproduction of a suite of understory herbaceous and shrub species (Collins and Pickett 1988; Hughes and Fahey 1991), but the creation of larger gap sizes may have more of an effect (Moore and Vankat 1986). Without knowing more about the specific land use history of this forest patch, it is

difficult to speculate on the role of past land use in the ability of this forest to support RT&E species (Cramer et al. 2008).

Contemporary conditions, including the dominance of pawpaw (*Asimina triloba*) and the size and location of West Woods, could also be factors in the lack of RT&E species found at this site. West Woods has the densest pawpaw stands we encountered in our surveys. In most areas of this forest remnant, pawpaw is a significant component of the lower canopy. Dense patches of pawpaw may be strong competitors for light, soil nutrients, and water, and the lack of palatability to deer may focus more of the effects of browsing on understory herbaceous vegetation (Baumer and Runkle 2010; Cole and Weltzin 2005; Slater and Anderson 2014). Recent research (Wassel and Myers 2025) found that areas under pawpaw have lower species richness and population sizes, and that community composition is less predictable than areas outside of pawpaw patches. The combination of these factors indicates that herbaceous plant populations under pawpaw patches may be more susceptible to the effects of ecological drift and demographic stochasticity. In an extensive pawpaw patch, like the one in West Woods, RT&E species with small population sizes may be more likely to go locally extinct, and dispersal from source patches is less likely (Wassel and Myers 2025). The siting of West Woods as a small, wooded island surrounded by agriculture likely exacerbates this effect (Brunet et al. 2021).

Aspect and Slope

Aspect and slope can influence the temperature, light availability, and soil moisture at a site, and in areas with high relief, or greater difference in elevation, can be a strong determinant of local plant community composition (Harrelson and Matlack 2006). In areas where spring ephemerals are a substantial component of the flora, south-facing slopes can provide areas of increased light levels and earlier snowmelt, which may help plants meet their energy storage requirements before canopy leaf-out (Neufeld and Young 2014). In rich mesic forests of the northeastern United States, Bellemare et al. (2005) found different plant communities occupying north versus south-facing slopes, with south-facing slopes supporting more species tolerant of warmer, drier conditions. The lack of a relationship between RT&E plants and aspect at ANTI could be explained by the fact that we looked at the distribution of RT&E species as a group. There may be species-specific responses to aspect that we are unable to detect due to the small number of occurrences and locations of the majority of species encountered in this study.

At ANTI, RT&E species occurred less often on shallow slopes and more often on steep slopes than expected by chance across the entire survey area, but their distribution across aspect categories closely matched the distribution of aspect categories across the areas forested in 1936. The relationship between slope and RT&E species occurrence at ANTI is easily explained by the fact that steep areas are unfarmable. These steep slopes were much more likely to still be forested in 1936, and it is these steep areas that were preserved where RT&E species are primarily found today.

Management Recommendations

Summary

This study is meant to inform National Park Service personnel on strategies to best manage and conserve RT&E plant species at ANTI. Based on our results, special attention should be given to those areas of the park that contain both Opequon-Rock outcrop complex soils and the Limestone Oak-Hickory Forest vegetation community. These two elements commonly co-occur due to the fidelity of the Limestone Oak-Hickory Forest vegetation for calcareous soils, making this community a good indicator of quality habitat for these target species. Additionally, the effect of land use shows that preserving areas that have been historically forested may be more consequential for RT&E species conservation than restoring areas that have reforested since 1936, regardless of soil type or forest overstory community. While slope seems to influence RT&E plant occurrences, this is more due to land use history, given that those steeper areas were less accessible and therefore saved from deforestation, allowing for more RT&E plant occurrences today.

Continued Surveys

The limestone outcrops preserved at ANTI provide critical habitat for many plant species that have otherwise been extirpated from the region. Ongoing monitoring should be a high priority—both to detect new occurrences of known species and to document any species not previously recorded in the park. Regular surveys of established populations are also needed to track changes in abundance and population dynamics over time. Survey efforts at Sherrick Woods were limited by the site's steep terrain and the large population of *C. concolor*. A more detailed survey would allow a more accurate estimate of *C. concolor* population size and enable more precise tracking of demographic trends and spatial patterns. Similarly, we were unable to survey some of the steeper slopes at Snavelly Ford and the eastern edge of Roulette Woods, where additional RT&E populations may occur.

Reforestation and Assisted Colonization

As ANTI continues to reforest gaps adjacent to existing woodlands, it is unlikely that RT&E species will naturally colonize these sites. Many of these species have limited dispersal capacity, and the legacy of past agricultural land use may further reduce site suitability. Although connecting habitat blocks could provide movement corridors, the small founder populations present at ANTI, the episodic nature of seedling recruitment, and the absence of effective long-distance dispersal mechanisms suggest that natural spread will remain slow (Corlett and Westcott 2013). Assisted colonization is controversial (Sandler 2010), but intentional introduction of RT&E species into reforestation sites could substantially accelerate establishment. A meta-analysis of 66 reintroductions of 27 rare North American plant species reported recruitment lags of 1–17 years, with an average of nearly 4 years (Albrecht et al. 2019). Using seed from locally abundant populations of *C. concolor*, *S. shortii*, *R. strepens*, and, to some extent, *D. tricornis* to establish experimental plantings in new forest patches would provide an opportunity to test the relative importance of land-use history versus dispersal limitation in shaping colonization success.

Deer and Invasive Plant Species

The most significant threats to RT&E species at ANTI today are browse by white-tailed deer and encroachment from invasive species, both of which the park is already addressing. A clearer understanding of the locations of major concentrations of RT&E species at ANTI will help the park target management actions to protect and conserve areas with a high density of RT&E plant species. Another potential issue is the changes that could occur in the understory due to the loss of ash trees (*Fraxinus* spp.) from attack by the emerald ash borer (*Agrilus planipennis*). Often opening of the canopy favors early successional, shade-intolerant species, many of which are invasive (Gougherty et al. 2023). We observed downed ash in many areas we surveyed, particularly in Snavelly and Sherrick Woods, and further encroachment of invasive species into areas with a high density of RT&E species could put these populations at risk. Areas that were forested in 1936 and already contain a high density of RT&E species should be prioritized for management to combat an increase in invasive plant species in the light gaps created by the deaths of these trees.

Trail Rerouting

Park personnel noted that sections of the southern portion of Snavelly Ford trail will eventually need to be rerouted to address issues with erosion and traversing outside of the boundary of the park. We walked this trail many times and are confident these areas were thoroughly surveyed. If the southwestern corner of Snavelly Ford trail is rerouted to stay within the park boundary, care should be taken to avoid the populations of *P. meadia* and *R. cynosbati* in this area.

Direct Human Impacts

Populations of several RT&E species can be seen from the Snavelly Ford, Sherrick Farm, and Three Farms trails. At Snavelly Ford, *R. strepens*, *C. bulbifera*, *S. shortii*, *H. maximum*, and *P. virginiana* are easily visible from the trail in the fall. In the spring, *D. tricornis* can also be seen from the Snavelly Ford trail. Hikers along the Sherrick Farm trail will encounter *R. strepens*, *S. shortii*, and *C. concolor*. Visitors using the Three Farms trail to hike past Roulette Woods will encounter the large patch of *R. strepens* that grows along this trail north of the footbridge.

Populations of *R. strepens* at Roulette Woods, of *P. virginiana* in zone 10 of Snavelly Woods, and possibly the population of *R. strepens* at Union Advance Woods are at risk of being mowed. In Roulette and Snavelly, these populations are immediately adjacent to the trail. We saw one individual of *P. virginiana* nearly be mowed when we were surveying Snavelly Woods and saw *R. strepens* definitely get mowed at Roulette Woods. The population of *R. strepens* at Union Advance lies adjacent to the large open grassy area between these woods and Antietam Creek, and mowing or other land management may impact that population as well. That being said, the *R. strepens* populations in Union Advance and Roulette Woods are sizeable, and mowing may be helping to reduce competition from other species. The effects of land management activities on these *R. strepens* populations should be investigated further.

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Appendix

The following tables indicate when target RT&E species are available for sampling in Maryland (Table 3) and expected versus observed occurrences of RT&E species by forest overstory community (Table 4), soil map unit (Table 5), 1936 forested area (Table 6), slope (Table 7), and aspect (Table 8).

Table 3. Flowering/fruiting/visibility period for target species arranged by optimal time of year in Maryland. An “X” indicates when RT&E species are available/visible for sampling in each month during the survey period (March–October). November through February is not shown because the target plant species are not visible during this period.

Species	March	April	May	June	July	August	September	October
<i>Erigenia bulbosa</i>	X	X	–	–	–	–	–	–
<i>Delphinium tricornes</i>	X	X	X	–	–	–	–	–
<i>Primula meadia</i>	X	X	X	X	–	–	–	–
<i>Heracleum maximum</i>	–	X	X	X	–	–	–	–
<i>Zizia aurea</i>	–	X	X	X	–	–	–	–
<i>Cubelium concolor</i>	–	X	X	X	–	–	–	–
<i>Physalis virginiana</i>	–	X	X	X	X	–	–	–
<i>Asplenium resiliens</i>	–	X	X	X	X	X	X	X
<i>Cystopteris bulbifera</i>	–	X	X	X	X	X	X	X
<i>Ribes cynosbati</i>	–	–	X	X	–	–	–	–
<i>Scutellaria nervosa</i>	–	–	X	X	–	–	–	–
<i>Liparis liliifolia</i>	–	–	X	X	–	–	–	–
<i>Liparis loeselii</i>	–	–	X	X	X	X	–	–
<i>Clematis viorna</i>	–	–	X	X	X	X	–	–
<i>Castanea dentata</i>	–	–	X	X	X	X	X	X
<i>Ruellia strepens</i>	–	–	–	X	X	X	–	–
<i>Carex hitchcockiana</i>	–	–	–	X	X	X	–	–

Table 3 (continued). Flowering/fruiting/visibility period for target species arranged by optimal time of year in Maryland. An “X” indicates when RT&E species are available/visible for sampling in each month during the survey period (March–October). November through February is not shown because the target plant species are not visible during this period.

Species	March	April	May	June	July	August	September	October
<i>Carex sparganioides</i>	–	–	–	X	X	X	–	–
<i>Scutellaria incana</i>	–	–	–	X	X	X	–	–
<i>Monarda clinopodia</i>	–	–	–	–	X	X	X	–
<i>Symphytotrichum shortii</i>	–	–	–	–	–	X	X	–
<i>Juglans cinerea</i>	–	–	–	–	–	–	X	X

Table 4. Expected and observed occurrences of RT&E species by forest overstory community for the total study area and for the 1936 forested area. Area values are given in square meters. Superscript letters (A, B, C) indicate significant differences among categories ($p < 0.05$).

Forest Overstory	Total Area	Proportional Total Area (m ²)	Expected Occurrences Total Area	Total 1936 Forested Area (m ²)	Proportional 1936 Forested Area	Expected Occurrences 1936 Forested Area	Actual Occurrences
Limestone Oak - Hickory Forest	176063.10	0.280	91 ^A	131233.10	0.475	153 ^B	203 ^C
Rich Red Oak - Sugar Maple Forest	78021.09	0.124	40 ^A	65157.44	0.236	76 ^B	26 ^A
Old-field Eastern Red-cedar Forest	73350.25	0.117	38 ^A	7921.68	0.029	9 ^B	23 ^{A,B}
Black Walnut Forest	30599.75	0.049	16 ^{A,B}	2527.13	0.009	3 ^B	21 ^B
Rich Floodplain Forest	60817.51	0.097	31	22527.42	0.082	26	21
Calcareous Mixed Deciduous Forest	98210.68	0.156	50 ^A	7350.74	0.027	9 ^B	15 ^B
Tuliptree Forest	61450.16	0.098	32 ^A	38273.50	0.139	45 ^B	14 ^A
Box-elder Floodplain Forest	7232.20	0.011	4	0	0	0	0
Mixed Deciduous Vine-Forest	42597.46	0.068	22 ^A	1223.47	0.004	1 ^B	0 ^B

Table 5. Expected and observed occurrences of RT&E species by soil map unit for the total study area and for the 1936 forested area. Area values are given in square meters. Superscript letters (A, B) indicate significant differences among categories ($p < 0.05$).

Soil Map Unit	Total Area (m ²)	Proportional Total Area	Expected Occurrences Total Area	Total 1936 Forested Area (m ²)	Proportional 1936 Forested Area	Expected Occurrences 1936 Forested Area	Actual Occurrences
Opequon-Rock outcrop complex	170420.32	0.272	88 ^A	103601.10	0.375	121 ^A	197 ^B
Ryder-Duffield channery silt loams	206712.66	0.329	106 ^A	74938.16	0.272	88 ^A	44 ^B
Ryder-Rock outcrop complex	83433.38	0.133	43 ^{A,B}	50526.47	0.183	59 ^A	29 ^B
Combs silt loam	33711.86	0.054	17	12827.40	0.046	15	25
Duffield silt loam	66910.73	0.107	34 ^A	3553.94	0.013	4 ^B	16 ^{A,B}
Funkstown silt loam	24082.72	0.038	12	3367.20	0.012	4	11
Hagerstown-Rock outcrop complex	26427.52	0.042	14 ^A	26152.09	0.095	31 ^A	1 ^B
Other	15983.55	0.025	8	981.50	0.004	1	0

Table 6. Expected and observed numbers of RT&E species occurrences in the 1936 forested area. Area values are given in square meters. Superscript letters (A, B) indicate significant differences among categories ($p < 0.05$).

Forested in 1936	Total Area (m ²)	Proportional Total Area	Expected Occurrences Total Area	Actual Occurrences
Yes	312483.90	0.497	161 ^A	248 ^B
No	315858.10	0.503	162 ^A	75 ^B

Table 7. Expected and observed numbers of RT&E species occurrences by slope category for the total area and the 1936 forested area. Area values are given in square meters. Superscript letters (B, C) indicate significant differences among categories ($p < 0.05$).

Slope ^A	Category	Total Area (m ²)	Proportional Total Area	Expected Occurrences Total Area	Total 1936 Forested Area (m ²)	Proportional 1936 Forested Area	Expected Occurrences 1936 Forested Area	Actual Occurrences
Nearly level	0–2.9%	50005.72	0.076	25	18811.29	0.067	22	15
Gently sloping	3–6.9%	125727.52	0.191	62	42983.50	0.152	49	36
Strongly sloping	7–11.9%	181484.96	0.276	89 ^B	50035.57	0.177	57 ^{B,C}	53 ^C
Moderately steep	12–19.9%	175185.83	0.266	86	62565.32	0.222	72	75
Steep	20–29.9%	88118.63	0.134	43 ^B	74122.63	0.262	85 ^C	107 ^C
Very steep	30–39.9%	33643.67	0.051	17	30811.96	0.109	35	35
Extremely steep	>40%	3328.70	0.005	2	3120.33	0.011	4	2

^A Slope data were retrieved from: https://www.nrcs.usda.gov/sites/default/files/2022-10/Basic_Soils_AK_Curriculum%20-%20UPDATED.pdf

Table 8. Expected and observed numbers of RT&E species occurrences by aspect category for the total area and the 1936 forested area. Area values are given in square meters. Superscript letters (A, B) indicate significant differences among categories ($p < 0.05$).

Aspect	Category	Total Area (m ²)	Proportional Total Area	Expected Occurrences Total Area	Total 1936 Forested Area (m ²)	Proportional 1936 Forested Area	Expected Occurrences 1936 Forested Area	Actual Occurrences
North	337.5–22.5	27130.92	0.041	13	10746.38	0.038	12	8
Northeast	22.5–67.5	57188.87	0.087	28 ^{A,B}	35621.24	0.126	41 ^A	15 ^B
East	67.5–112.5	120397.90	0.183	59	71703.59	0.254	82	77
Southeast	112.5–157.5	146281.80	0.222	72	68151.25	0.241	78	102
South	157.5–202.5	79266.39	0.121	39	36252.10	0.128	41	35
Southwest	202.5–247.5	80632.85	0.123	40	27120.43	0.096	31	47
West	247.5–292.5	103729.70	0.158	51	23958.57	0.085	27	32
Northwest	292.5–337.5	42854.07	0.065	21	8897.77	0.032	10	7

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