Habitat Survey of the Eastern Section of Hollow Rock Nature Park

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Acknowledgements

This project was funded by the Durham County Open Space Program and follows the larger, multi-taxa survey conducted by the North Carolina Biodiversity Project of the natural areas owned and managed for conservation by the Program. We thank the staff of the Program for sharing information about the site. We also want to thank Bruce Sorrie, a member of the North Carolina Biodiversity Project for his help in identifying some of the plant specimens.

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The extensive bottomland forests and wetlands located along New Hope Creek in Durham County have long been a focus of conservation interests, with decades-long efforts resulting in the protection of several key tracts. Less well-known but now nearly vanished under development are the low ridges of upland habitats that were once common across the Triassic Basin. In a survey of the New Hope Bottomlands conducted by the North Carolina Biodiversity Project in 2021-22, the floodplain habitats were again the main focus. However, we also made some visits to a tract of upland forest located within the eastern section of Hollow Rock Nature Park that not only was in excellent condition but that had a number of features that sets it apart from the typical forests of the Piedmont uplands: dry-xeric species such as Post Oak were frequently observed growing next to bottomland species such as Ironwood; basophilic species such as Northern Shagbark Hickories were found growing above such acidophilic species as Lewis's Heartleaf and thickets of blueberries.

Unfortunately, we were not able to give as much attention to that tract as to the larger area of lowlands. This current project is an attempt to give this tract the attention it merits as possibly one of the best examples of its vanishing type.

Location and Physical Features of the Study Area

As shown in Figure 1, the study area includes the portion of Hollow Rock Nature Park located on the east side of Pickett Road, covering 45.6 acres. The entire park was included in the 2021-22 inventory conducted by the NCBP and the area included in the current study was identified as particularly noteworthy, both for the maturity of its forest and for its unusual composition, mixing elements of dry oak-pine-heath vegetation associations with those of basic mesic associations. This mixture, moreover, appeared to be fairly pervasive over the entire study area, not divided into distinct communities. As such, this stand appears to be particularly amenable to analysis using compositionally distinct but spatially overlapping habitats, a distinctive feature of the NCBP approach to ecological analysis.

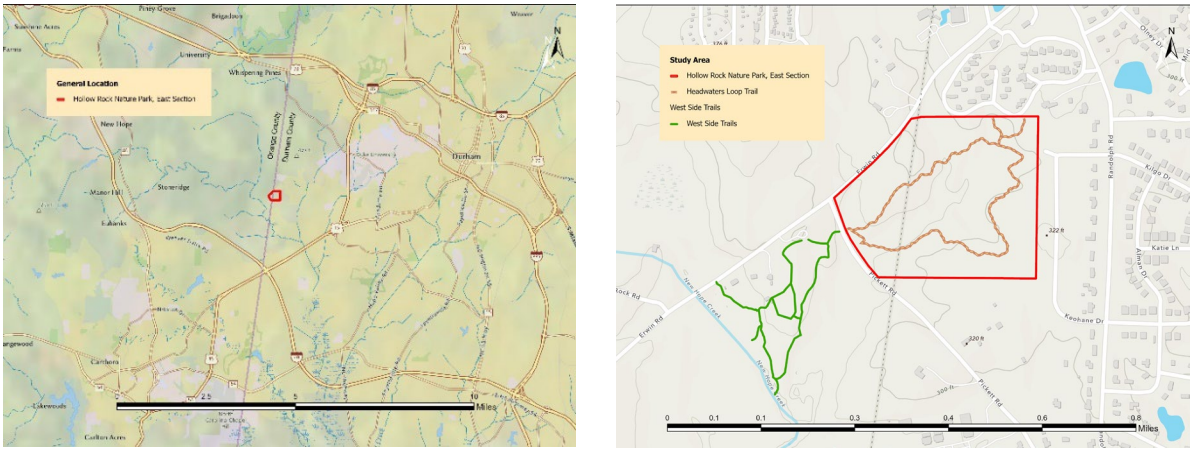


FIGURE 1 STUDY AREA LOCATION

Geography and Geology

The study area is located close to the western edge of the Triassic Basin, a geographic formation that originated approximately 220 million years ago when the African continental plate pulled away from North America. This process resulted in the creation of fault lines in the continental crust and the downward slippage of large blocks of terrain. The lowlands formed as a consequence rapidly filled with water and stream-born sediments, creating layers of benthic soils that compacted and fossilized to form sandstones, siltstones, coal beds, and other sedimentary rock formations. Somewhat later in geological time, these sedimentary formations were intruded along the fault lines running through the basin by diabase and other igneous rocks having a very different chemistry than the adjoining rocks: mafic rather than felsic (see Bain and Harvey, 1977; Bain and Brown, 1981).

As shown in in Figure 2, the study area is located close to the western edge of the Triassic Basin, with the crystalline rock formations typical of the Piedmont located only a short distance away west of Erwin Road. The formations underlying the study area are primarily sedimentary rocks, classified as TRc: conglomerates, fanglomerates, sandstones, and mudstones (1985 North Carolina Geologic Map, North Carolina Geological Survey, NC Center for Geographic Information and Analysis).

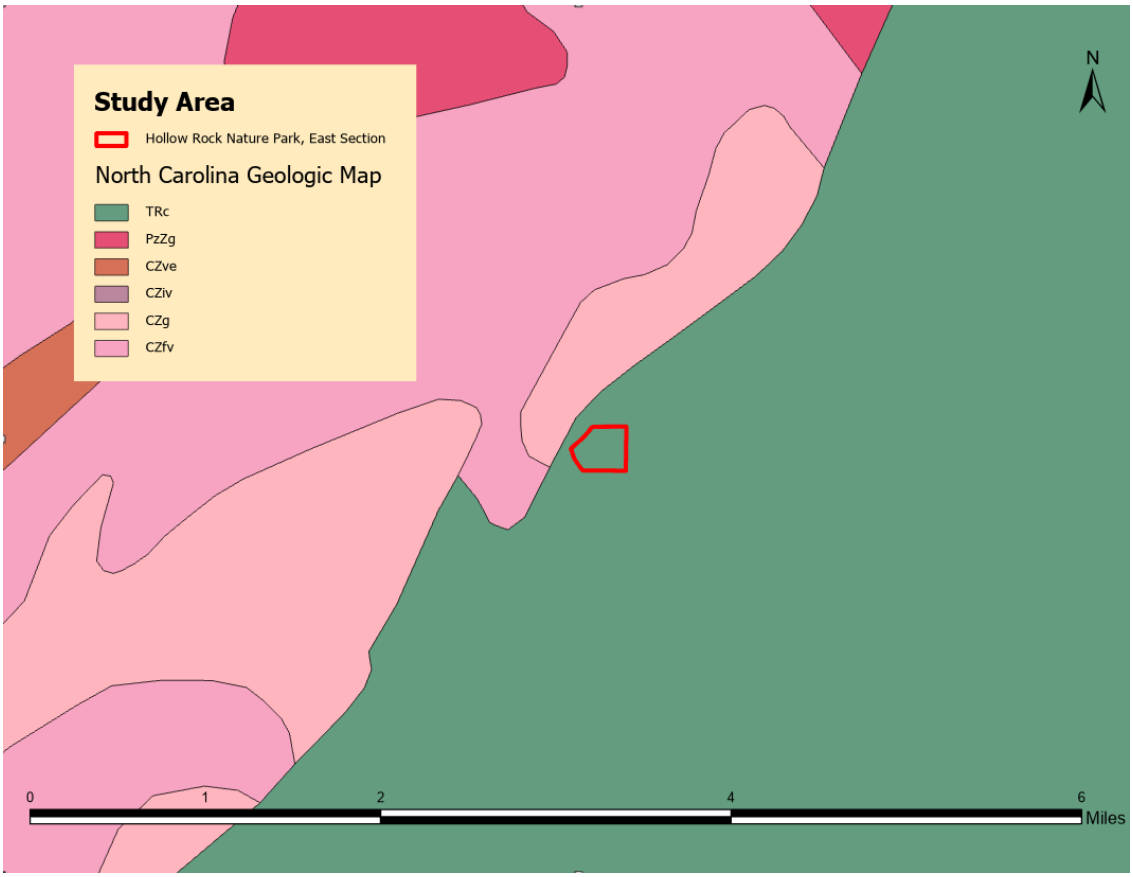


FIGURE 2. GEOLOGICAL FORMATIONS OF THE STUDY AREA

Rather than the flat terrain of the original lakebed of the Triassic Basin, the area containing the study area has been uplifted and subject to strong stream-cutting action, leading to the hillier and more dissected upland terrain shown in Figure 3.

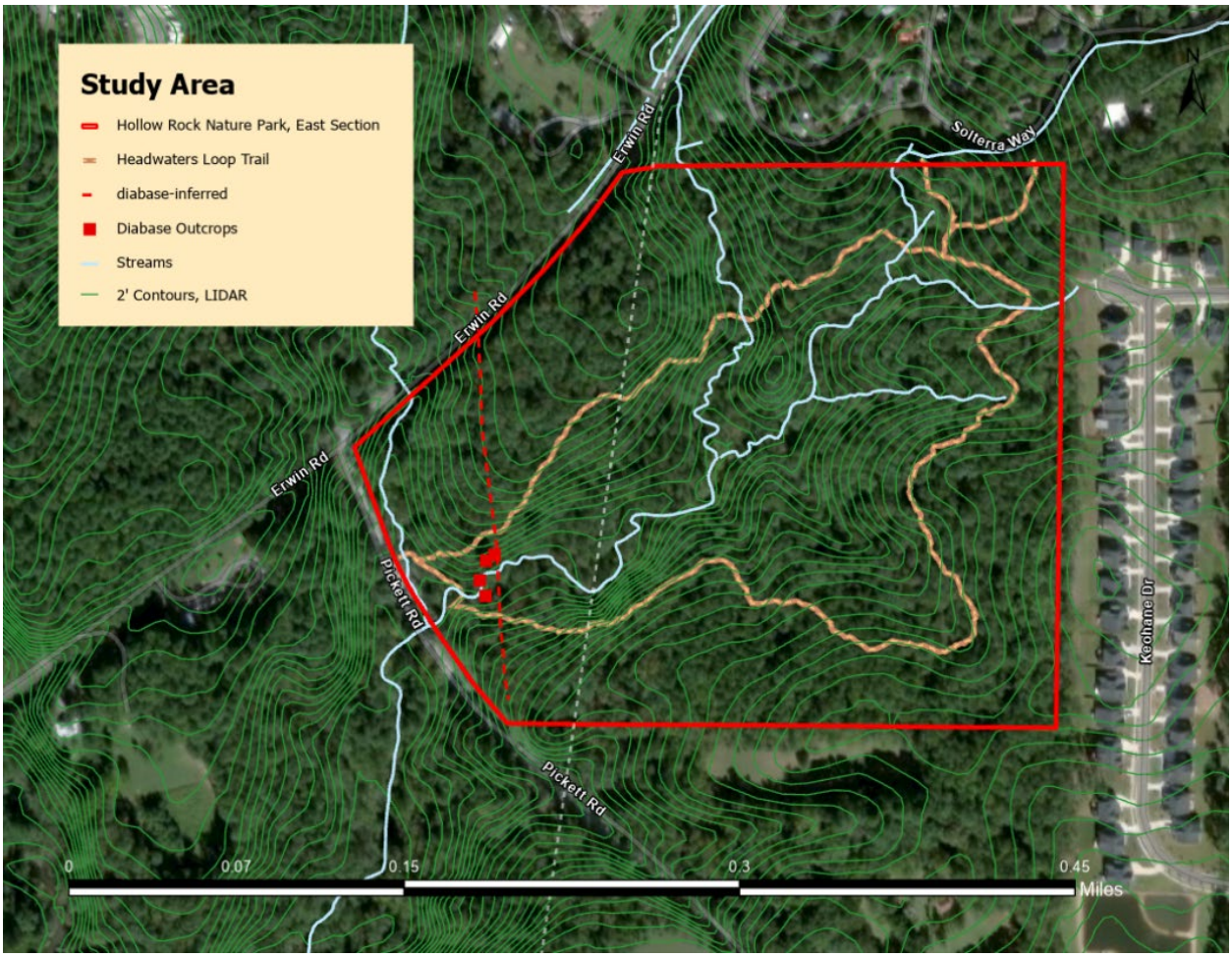


FIGURE 3. TOPOGRAPHY OF THE STUDY AREA

As a consequence of the stream-cutting, large outcrops of the underlying sedimentary formations are exposed at a couple of sites along the creek that flows through the center of the study area. Examples are shown in the photos below.

In addition to these sedimentary formations, there is at least one small dike of diabase, an intrusive igneous rock formation, that runs across the western side of the study area, crossing both branches of the foot trail as well as the creek. This formation is depicted in an Orange County map of diabase intrusions, indicated by the red line in Figure 3. However, the surface outcrops are located slightly to the west of this line as are shown by the red squares on the map. Examples of some of the boulders from those locations are shown below, with the high iron content indicated by the rusty brown patina typical of diabase

Soils

Rather than still receiving sediments transported by creeks, such as is the case with the alluvial deposits of the bottomlands along New Hope Creek, the soils within the study area have all formed in place secondarily, as the sedimentary rocks and diabase have weathered over the past hundreds of millions of years.

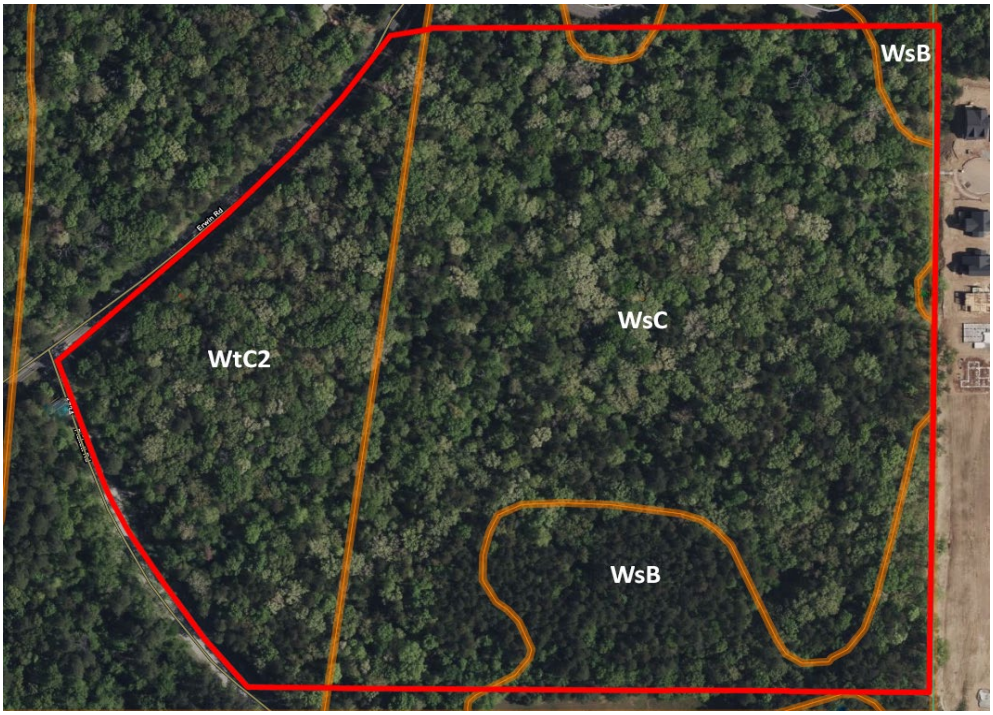


FIGURE 4. SOILS OF THE STUDY AREA

As shown in Figure 4., the study area is entirely underlain by soils in the White Store Series, which are specifically derived from weathered Triassic Basin sedimentary formations. The specific map units are described in the following table[1]:

Map Unit	Map Unit Name	Ecological Site
WsB	White Store sandy loam, 2 to 6 per cent slopes	Triassic basin upland forest, seasonally wet
WsC	White Store sandy loam, 6 to 10 per cent slopes	Triassic basin upland forest, expansive clay, seasonally wet and dry
WtC2	White Store clay loam, 6 to 15 percent slopes, moderately eroded	Triassic basin upland forest, expansive clay, seasonally wet and dry

According to the Official Series Description (National Cooperative Soil Survey), this series consist of fine sandy-loam surface soils down to 10 inches, underlain by a layer of montmorillonite (smectite) clays that may be over 40 inches thick (illustrated in the photo below, taken along one of the creeks in the study area).

While the surface soils are highly permeable, the deeper clay layer is highly impermeable and has a high shrink-swell capacity: significantly expanding when wet and contracting when dry. The seasonal swings in moisture, along with the impermeability – inhibiting root penetration – is believed to strongly determine the plant species capable of growing on soils with a high montmorillonite content. Where such clays form from diabase or other mafic rock formations, the high calcium and magnesium content and relatively high pH of the soils favors species that

[1] Map and soil descriptions obtained from the USDA Web Soil Survey, available at: https://websoilsurvey.nrcs.usda.gov/app/

are basophilic and/or calciphilic (Dayton, 1966). However, the White Store clays weathered from primarily felsic Triassic Basin sandstones are acidic and nutrient poor Consequently, they support a different, although somewhat overlapping, set of species (see discussion of Hardpan Natural Communities in Schafale, 2023).

Past Land Use

In addition to abiotic factors such as substrate type and moisture regime, past exploitation for agriculture, silviculture, and other human uses strongly influences the species that are currently present at a given site. The following historic aerial photos of the study area indicate that much of it has escaped being cleared since at least the early part of the Twentieth Century.

FIGURE 5. CHANGES IN LAND USE, 1940-2024

This is somewhat consistent with the general uses of White Store soils. According to the Official Soil Series description, only about a third of the total area covered by White Store soils is in cultivation and pasture but with large areas taken out of row crop production because of erosion. In the case of this particular site, the uneven terrain may have been particularly unsuitable for cultivation and there are no obvious plow lines or rock piles that indicate its past use for this purpose.

The remaining two-thirds of the area covered by White Store soils are covered with forests consisting of loblolly and shortleaf pines, oaks, hickories, and gums, which fits the description of the forest now present within the study area. The stand shown in the 1940 aerial photo also appears to represent mainly hardwoods, which is more clearly shown in the later photos. Within the current boundaries of the study area, only an area along the southern boundary, bordering a small cultivated field, appears to have been converted to a pine stand. A stand of Loblollies of approximately the same age – judging from the aerial photos – has also long existed on the portion of the Hollow Rock preserve on the west side of Pickett Road.

The maturity of the stand within the study area is also indicated by the presence of large trees scattered over most of its extent, as depicted in Figure 6.

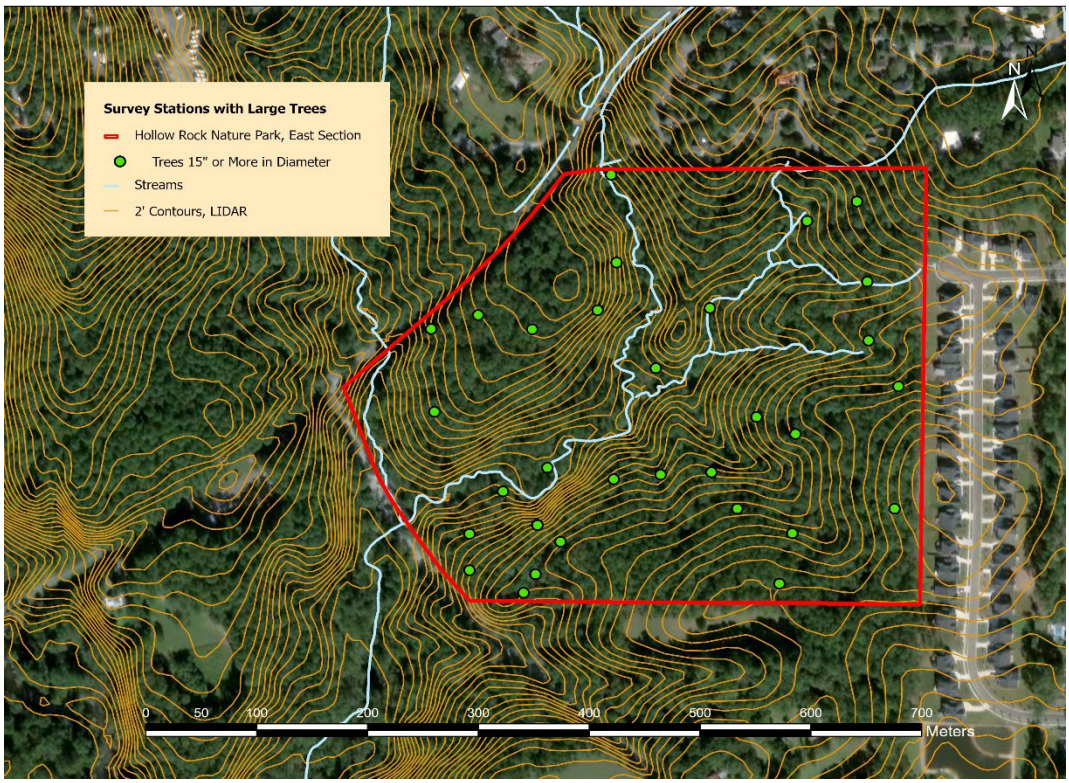
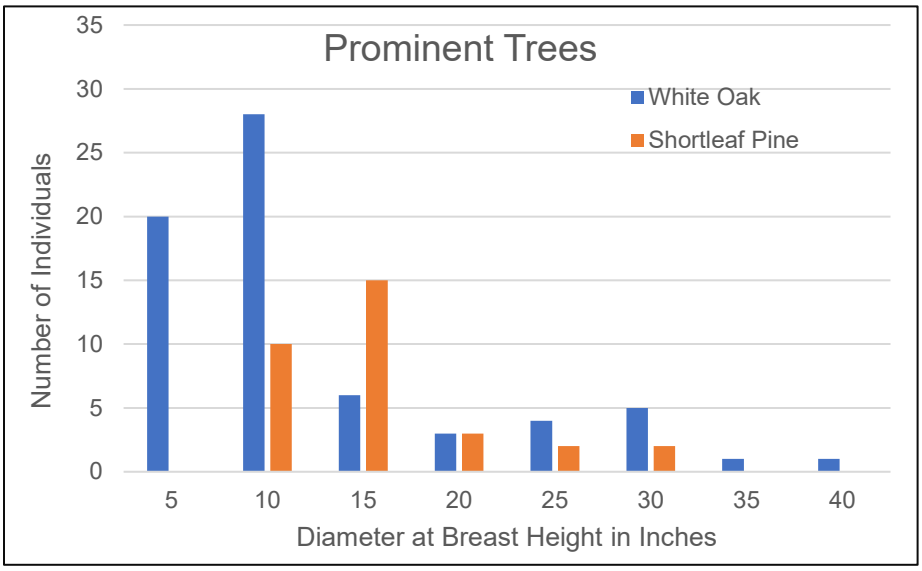


FIGURE 6. DISTRIBUTION OF LARGE TREES RECORDED IN THE SURVEY

The histogram below shows the size distribution for two of the largest species, White Oak and Shortleaf Pine, but there are also large individuals of several other species. For example, a Mockernut Hickory with a dbh greater than 30" is located next to the northern branch of Headwaters Loop Trail, where it is crossed by the diabase dike (see photos below).



The presence of scattered, very old Shortleaf Pines, however, indicates that large patches may have been opened up in the past, possibly by fire or wind storms. Selective cutting may also be responsible, especially in the creation of the pine stand in the southern part of the study area (where old trees were not recorded), but given the wide distribution of old trees, it seems unlikely that the site has ever been completely cleared, for either cultivation, pasture, or silviculture. In an archaeological survey of the area (Legacy Research Associates, 2013), only an old roadbed – now a wetland – and remnants of a rock dam were found, but no other post-European settlement artifacts.

Methods

The original study plan was to conduct a survey similar to the habitat-focused project conducted in the New Hope Creek floodplain (see Hall and Tingley, 2023), with attention selectively centered on Northern Shagbark Hickories and a few other targeted species. At each location, only a few other species were included in the field notes, primarily other tree species or shrubs.

After surveying an initial set of points in May, 2024, it became apparent that the composition of habitats within this preserve was more complicated than originally thought, and the selective sampling method was changed to a more systematic approach, aimed at a more comprehensive coverage of habitat types. A set of semi-random coordinates was created using ArcGis using the Random function, with the restriction that the points be separated by 50 or more meters. The coordinates of these points were then uploaded into a Garmin Montana GPS unit which was used to navigate to these points in the field.

Forty-four points were initially selected for the Durham County portion of the study area, followed by fifteen for the Orange County section. These points (in green), along with the original 15 used in the selective sampling (in purple) are shown in Figure 7.

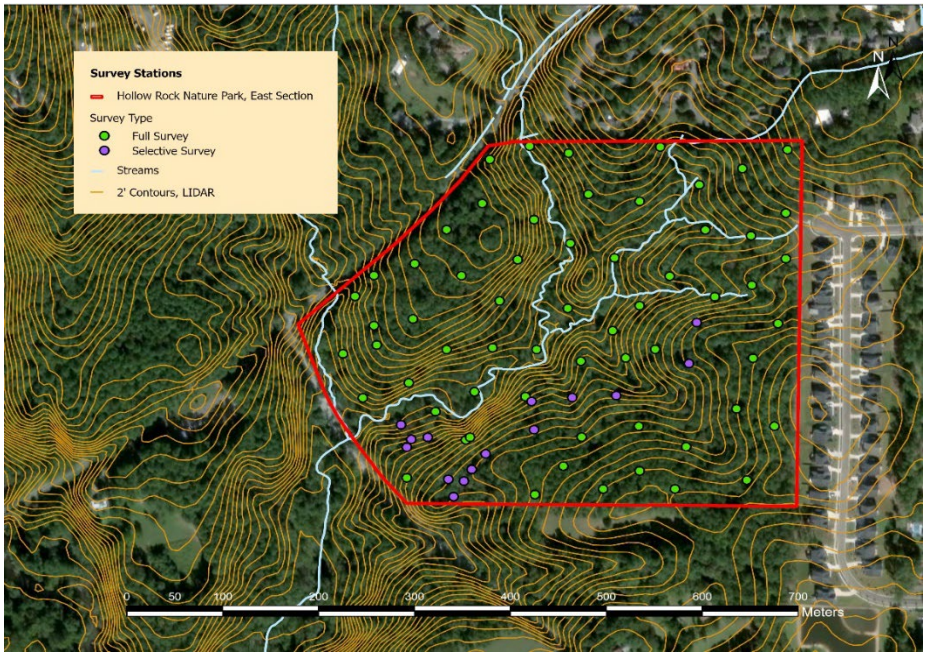


FIGURE 7. SURVEY PLOTS

Two additional points were added in the field, one to capture the features at a site used for moth sampling done in 2023 and another to capture species on a steep slope that was otherwise missed by the initial points in that area. In both cases, these points were located less than 50 meters from one of the initially selected points. That brings the total of fully surveyed plots to 61. Only these plots are used in the quantitative analysis, although in some cases, the presence of certain species recorded in the initial survey, e.g., *Hexastylis lewisii*, is mentioned in the results.

At each of the points selected for the comprehensive survey, a species list was compiled for the vascular plants located within a five-meter radius of the selected point. A few species – mainly grasses and sedges – were not identified to species due to the absence of flowers, fruit, or other structures needed for their determination. Special attention, on the other hand, was given to species belonging to one of the habitat categories used in our analysis.

For each of the identified species, several factors were recorded to estimate their successful occupancy of the study area. Evidence of ongoing reproduction was based on the presence of seedlings as well as mature, reproductive individuals. For tree species, three age classes were recorded: seedlings/transgressives, saplings (less that 1" dbh but at least 4' high), and all individuals larger than 1" dbh. For individuals in the last category, all were counted and their dbh estimated visually. Over the study site as a whole, the presence of all of these age classes is considered evidence of successful occupancy, i.e., that the presence of these species represents the presence of truly suitable habitat rather than just "population sink" conditions, where individuals can survive over at least the short term but reproduction is generally unsuccessful.

For shrubs, herbs, and ferns, on the other hand, all individuals other than obvious seedlings were considered to represent mature, reproductive individuals. The presence of any individuals of these species within a plot is treated as indicating the presence of suitable habitat.

Habitat Analysis

The North Carolina Biodiversity Project describes, maps, and evaluates the ecological features of a site based on the habitats it possesses. Habitats, as defined here, are distinguished both by a unique combination of habitat factors and by a unique set of species that show a high degree of fidelity to those factors: 80% or more of their occurrences are located where those factors are present.

The existence of a residential, breeding population of one or more of the species that are members of a particular habitat – termed the Determining Species of that habitat – is sufficient to identify an occurrence of that habitat at a given location. The site must, in fact, have at least one such Determining Species in order qualify as a habitat occurrence – habitats are ecological entities and they must have living inhabitants, not just the habitat factors, in order to qualify as an occurrence.

Although habitat occurrences are defined and evaluated ideally using all the Determining Species present at a site – from vertebrates to fungi to protists –vascular plants were the focus for this survey since they are the easiest to detect and map and finding a resident population of any of these species is sufficient to document the presence of a given habitat.

A total of 82 plant species were recorded in this survey, representing 31 of the habitats currently defined by the NCBP[2]. Only a selected number are included in this analysis, however – those that illustrate the most distinctive features of the study area.

[2] These will be described in the Habitats of North Carolina website, which is currently under development.

These habitats[3] include:

Dry-Xeric Forests and Woodlands
Rich Upland Hardwood Forests
Rich Wet-Mesic Hardwood Forests
Wet Hardwood Forests
General Hardwood Forests
General Forests
Exotic Invasives

For each of these habitats, a map is produced using ArcGis Pro showing its overall distribution within the study area, with the number of species recorded at each survey point shown using color-graduated symbols. These maps are used to determine if there is any detectable spatial pattern, where concentrations of occupied plots are associated with particular topographic or geologic features.

A more detailed assessment of the viability of a habitat comes from an analysis of the Determining Species present within the site. A viability score is first assigned to each species following guidelines established by NatureServe for estimating species' occurrence ranks (see Hammerson et al., 2020). These scores are intended to represent the likelihood that a given occurrence will survive over the next twenty to thirty years, but in the NatureServe approach are expressed as ordinal level estimates. For the purpose of evaluating entire groups of species, however, we assign numeric values that estimate these scores as probabilities of survival (PS values). Unlike ordinal level values, these numeric values can be combined across all of the species in a group, producing a measure of the quality/survival at the level of the habitats.

A summary of these scores is given in the following table:

Rank	Definition	PS	Ranking Guidelines
S	Secure	1.0	Landscape-level habitat and population extent, excellent habitat quality, strong level of protection, management aimed at the protection of the species and its ecosystem, no major threats
A	Excellent Viability	0.9	Large population, good quality habitat, evidence of ongoing, successful reproduction, no major threats
B	Good Viability	0.8	Smaller populations but with approximately normal density, good quality habitat, evidence of reproduction, low degree of threats
C	Fair Viability	0.6	Small population, reduced density, sub-optimal habitat, some evidence of reproduction, moderate degree of threats
D	Poor Viability	0.4	Small population with reduced density, no direct evidence of reproduction, habitat is reduced or degraded, major threats are possible, conservation actions have only a low probability of success
D-	Very Poor Viability	0.3	Same as for D but with significant identified threats or observed population declines, high probability of significant threats, low chance of success for conservation actions

[3] These groups actually represent combinations of several of the habitats currently defined by NCBP. For example, the Dry-Xeric Forests and Woodlands used here combines the following habitats: General Dry-Xeric Hardwood Woodlands, General Dry-Xeric Pine Forests and Woodlands, and General Upland Heath Thickets.

Rank	Definition	PS	Ranking Guidelines
M	Moribund	0.2	Species is still present at the site but can be found only with difficulty compared to even D level occurrences, no conservation potential exists other than translocating individuals to a more secure site
F	Failed to Find	0.1	Species could not be found in recent surveys but previously recorded at the site and could still exist in very low numbers
H or X	Historic or Extirpated	0.0	Evidence for extirpation, or the species has not observed at a site in over thirty years or no evidence exists that the species ever occurred at a site

Additionally, a rank of E is used for Extant populations but where not enough evidence exists to meet the ranking guidelines; the species is given a PS of 0.5, indicating an equal probability of either survival or extirpation over the next thirty years. Combinations of ranks are also used, where the corresponding PS values are calculated by linear interpolation. A CD score, for example, confers a PS value of 0.5, again indicating an even chance of survival, which is intermediate between the better-than-even chance of survival of a C score and a better-than-even chance of extirpation indicated by a D score.

Note that all of these ranks depend on species-specific considerations as to what constitutes a large population, normal density, reproductive rates and measures of success, habitat requirements, nature of threats, etc. For example, an A-level occurrence of the normally sparsely distributed Dwarf Pawpaw can be estimated based on the presence of far fewer individuals than what would be required for a White Oak. In all cases, expert judgement can play an important role, both in determining the rank and in estimating the PS values.

By estimating viability as probabilities of survival, meaningful group estimates are obtained by summing the PS values across the species. By interpreting them as survival probabilities, adding these values produces the expected number of species that will survive across the estimation period. For example, if three species have PS values of 0.1, 0.5, and 0.7, then the number of species expected to survive (EPS) over the next thirty years is 1.3. Conversely, the number of expected extirpations (EPE) can be calculated by subtracting the EPS value from the number of species. In the example above, EPE = 3 – 1.3 = 1.7. This measure is used to determine priorities for conservation action; the higher the expected number of extirpations, the greater the need of that habitat for effective conservation.

One other group measure that is particularly useful for the analysis of individual sites is the mean probability of survival, $\overline{x}$ PS, calculated by dividing EPS by n, the total number of species, including those that were expected but not recorded in a survey. This measure varies from 0, where none of the species are present, to 1, where all species are present and completely secure from extirpation (i.e., all PS = 1). As such it is a measure of the quality of the habitat for these species at this particular site.

Both the EPE and $\overline{x}$ PS can also be calculated based just on the species observed within the study area. The EPE value in this case again indicates priorities for conservation, but at the level of the individual site rather than at the level of the entire state. This site level $\overline{x}$ PS, correspondingly, is an indicator of the quality of the habitat for these species within this particular site and can be contrasted to that calculated for the expected species overall.

Dry-Xeric Forests and Woodlands

Recorded Species:
Juniperus virginiana
Pinus echinata
Quercus stellata
Quercus marilandica
Vaccinium tenellum
Vaccinium pallidum
Vaccinium stamineum

Species in this habitat range from the mountains to the outer coastal plain, occupying a range of drought-prone terrains and substrates, including rocky summits, south-facing bluffs, dry sandhills, and well-drained, sloped hardpans. A total of 59 of the 61 full survey plots (97%) contained at least one member of this group. Sixteen plots (26%) contained four or more and one contained six (the max). The distribution of these occupied plots is shown in Figure 8.

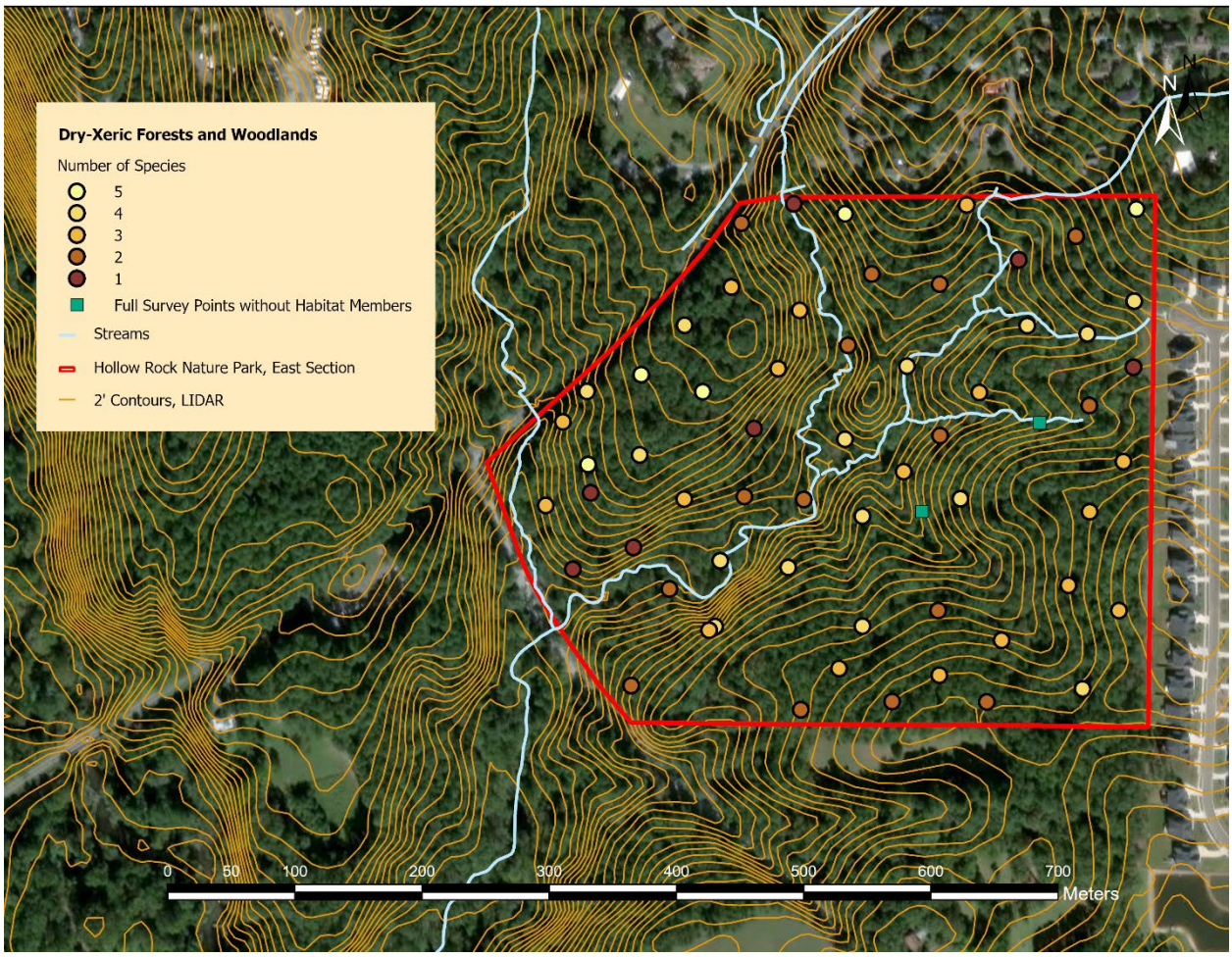


FIGURE 8.

Although species associated with dry-xeric habitats typically occur in exposed ridge tops or steep south-facing slopes, no such restrictions are evident in Figure 6. Instead, species belonging to this habitat are found on slopes of all aspects, as well as down in the creek bottoms that run through the study area. The drought-prone properties of high shrink-swell clay soils found throughout this site, along with their rapid drainage, are more likely to be responsible for the observed distribution of this habitat within the study area; even low-lying areas and north-facing slopes are affected by these factors.

***Juniperus virginiana* (Eastern Red Cedar)**. Although often associated with successional fields and woodland edges, this species was one of the most commonly encountered in this survey, including well within the interior of the study area. While it usually occurs within fairly dry forests, especially those with mafic soils, Schafale (2023) also lists it as a member of the Mixed Moisture Hardpan Forest, a natural community characterized by montmorillonite clays with strong swings in moisture, but also usually possessing a mafic chemistry. In general, this species prefers soils with higher pH or higher nutrient content than acidic soils such as White Store.

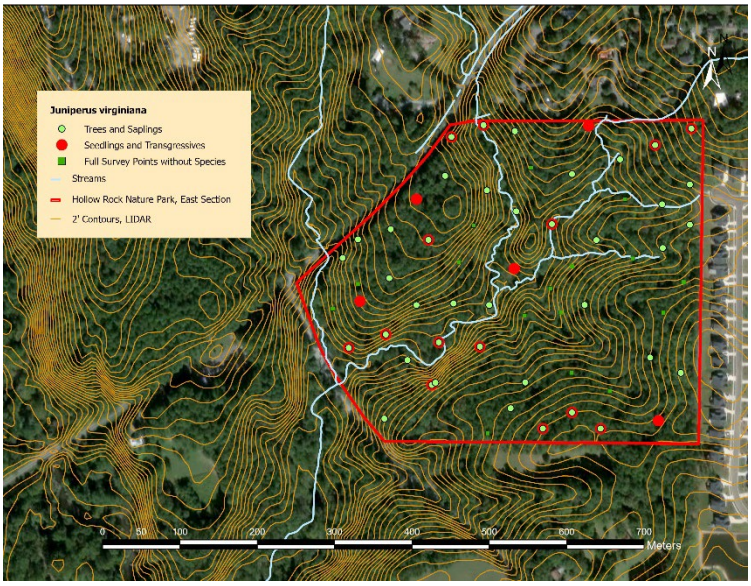


FIGURE 9

Red Cedars were found in 49 of the 61 (80%) of the full sampling plots, including in 19 plots as seedlings/transgressives, 19 as saplings, and 30 as at least pole-sized trees. Although dead snags were also observed in 23 plots, several large living specimens were observed, including two on a creek terrace that were approximately 14-15” in diameter.

Based on its high density and evidence of successful, continued reproduction, this occurrence seems viable for the immediate future, although the reduction of the extent of this particular stand, along with its isolation make it vulnerable to even fairly localized extirpating events, particularly fire. It also appears to lack a metapopulation structure that would allow survival of refugia within the study area, forming the basis for within-site recolonization following the end of a disturbance event. We estimate that it has an AC viability score, corresponding to a 0.75 probability of surviving over the next thirty years.

***Pinus echinata* (Shortleaf Pine)**. In North Carolina, Shortleaf Pines are typically found in dry upland forests (LeGrand et al., 2024) but elsewhere grow in floodplains or other sites with clay-rich soils (Lawson, 1990). Their ability to grow without a taproot, sending out a dense network of lateral root instead, may be an important adaptation to shallow, impermeable soils such as hardpans. Schafale (2023 includes Shortleaf Pines as a frequent associate of the Mixed Moisture Hardpan Forest. Lawson mentions, however, that this species does not grow well on substrates

with high pH or high calcium content, characteristic features of montmorillonite clays that develop from mafic rock formations.

This species additionally requires openings for successful seedling establishment and growth. It appears to be fairly fire-tolerant as mature trees and may require fire to create the openings necessary for seedling establishment and growth. On the other hand, mature trees can persist through succession to hardwood-dominated forests, with some individuals reaching up to two centuries in age. These individuals continue to produce seeds as long as there are enough of them to pollinate one another, and are able to take advantage of any disturbance event that comes along to open up the canopy sufficient for regeneration.

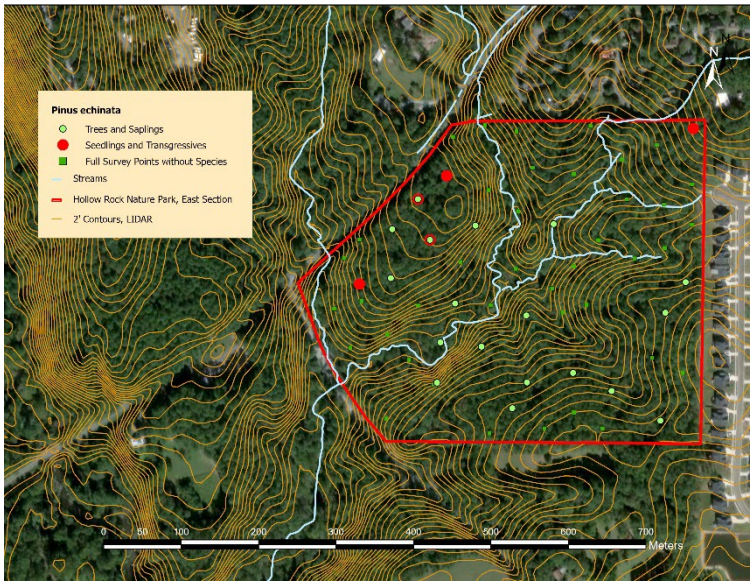


FIGURE 10

Mature Shortleaf Pines are found throughout the study area, occuring on ridges, slopes of various aspects, and creek terraces. A total of 26 plots (43%) contained individuals of this species. Five plots contained seedlings/transgressives, eighteen mature trees, and three dead snags.

Although this species is likely to persist indefinitely within the study area as mature trees, production of new generations probably will require a fire or some other substantial disturbance to open up the canopy. With the increasing encroachment of development right up to the boundary of the preserve, prescribed burning will be difficult, if not impossible, to implement. However, intense wind storms also play a role, especially in a stand with a large number of old trees. Selective cutting could also duplicate some of these effects. Consequently, the potential still exists for a reproducing population of Shortleaf Pines to persist within the study area.

We rate the viability of this occurrence as AC, giving it an estimated 0.75 probility of surving over the next thirty years.

***Quercus stellata* (Post Oak).** This species closely resembles Shortleaf Pine in the range of factors that govern where it grows: usually dry upland forests but also drier portions of floodplains, often where there is a high clay content and usually where the soils are somewhat acidic (LeGrand et al., 2024). Also like Shortleaf Pines, Post Oaks are shade intolerant, requiring openings for seedling growth (Stransky, 1990). They are also fire tolerant, re-sprouting vigorously following a burn and benefiting from its opening up of the canopy. Schafale (2023) includes Post Oak as a constituent to hardpan forests, including those characterized by basic soils.

Post Oaks are widely but fairly sparsely distributed across the study area, as shown in Figure 11, occurring primarily in the upland areas but with some also found in the creek valleys. They appear to be less common than Shortleaf Pines, possibly reflecting lower persistence of mature trees within stands that have not been disturbed for long periods of time.

Post Oaks were found in 19 of the 61 (31%) full survey plots. Immature specimens were difficult to identify but were recorded in five plots. Pole-sized trees and larger were recorded in eight plots. Four of these had a dbh of 15" or greater. The largest – growing on a narrow terrace close to the bank of a creek -- had a dbh of over 30".

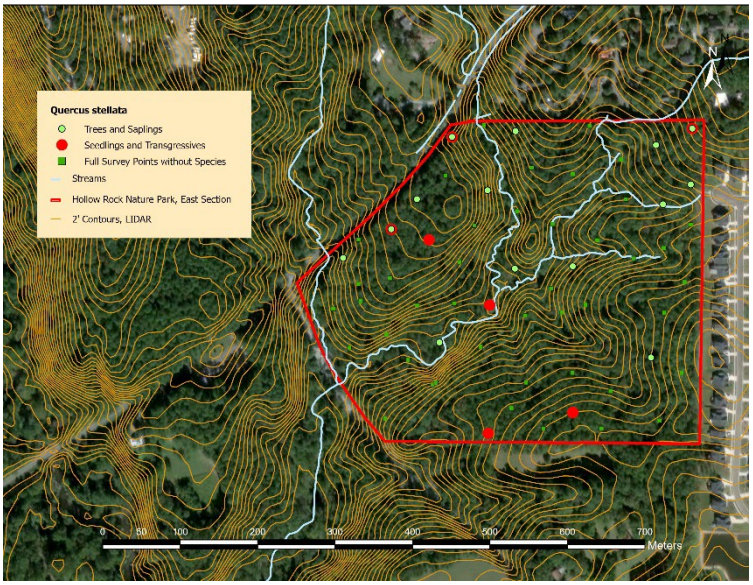


FIGURE 11

Without periodic disturbances that open up the canopy, Post Oaks are likely to continue to decline within the study area, probably at a higher rate than Shortleaf Pines. We estimate its viability score as BD and a 0.6 estimated probability of surviving over the next thirty years.

***Quercus marilandica* (Blackjack Oak).** This species is closely associated with Red Cedars, Post Oaks, and Shortleaf Pines, all co-occurring at many dry-xeric sites, especially where clay soils exist. Blackjack Oaks, however, are much scarcer within the study area than those species, recorded within only 6 plots (10% of the total) and all represented by saplings or transgressives (some of which may have been confused with those of Black Oaks and Southern Red Oaks). A few more mature specimens were also observed in the drier, more open portions of the uplands.

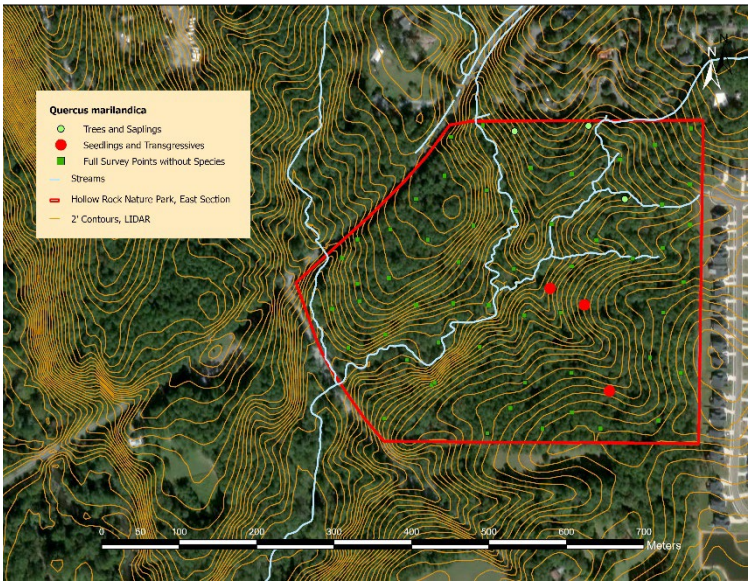


FIGURE 12

This fairly small tree may be declining as the stand matures and disturbances decrease that create the openings necessary for its regeneration. We estimate the viability score of this occurrence as CD, giving it an estimated 0.5 probability of surviving over the next thirty years.

***Vaccinium tenellum* (Small Black Blueberry) and *Vaccinium pallidum* (Hillside Blueberry).** These two low-bush blueberries form patches or extensive thickets in a wide range of dry-xeric woodlands, typically on acidic substrates (LeGrand et al., 2024). Both are characteristic of the Xeric Hardpan Forest (Acidic Hardpan Subtype) (Schafale, 2023).

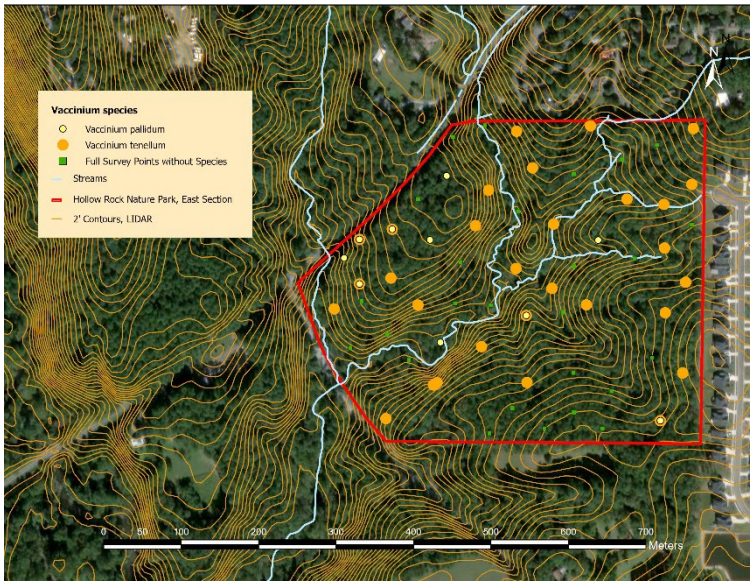


FIGURE 13

Both of these species benefit from fire or other disturbances that open up the canopy but are capable of persisting and reproducing to some degree in the shade. *Vaccinium tenellum*, in particular, can be numerous in fire-suppressed woodlands (LeGrand et al., 2024). Within the study area, *tenellum* was recorded at 30 of the 61 (49%) full survey plots. It was missing mainly from the area converted to Loblolly Pine along the southern border, an area also mapped as having the WsB soil type. We estimate the viability score for this species as AC, producing a PS value of 0.75 over the next thirty years.

Populations of *pallidum*, on the other hand, decline with age but can be rejuvenated by fire (Tirmenstein, D. A. 1991). In the study area, no extensive patches of this species were seen, unlike sites that are subject to frequent burns. This species was also recorded at only ten plots (16%). We estimate its viability score, consequently, as CD, and its PS value as 0.55.

***Vaccinium stamineum* (Deerberry).** This is another species of low-bush blueberry and has much of the same habitat characteristics as *V. tenellum* and *pallidum*. However, it is more tolerant of soils with a higher pH and may be the only member of this genus to be found in Basic Oak-Hickory communities or other glades and barrens with similar pH characteristics (LeGrand et al., 2024).

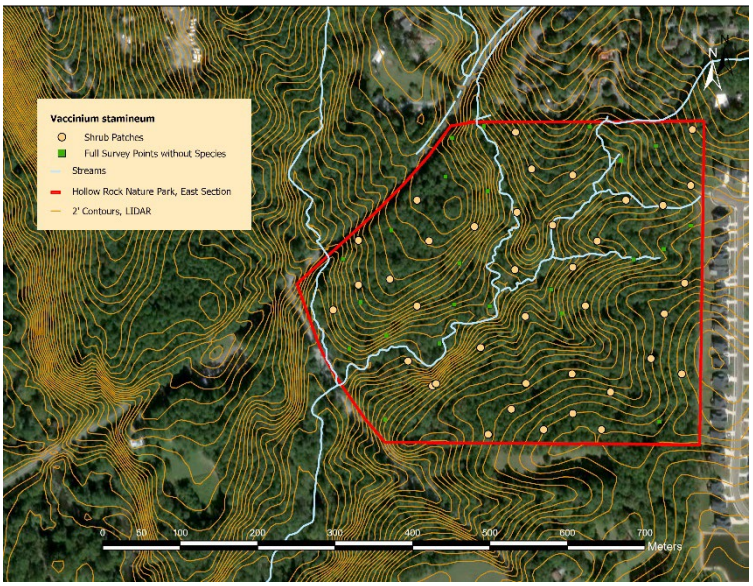


FIGURE 14

This species was more widely distributed than the previous two members of this genus, occupying a greater proportion of the preserve. It was also recorded more frequently, at 38 (62%) of the full survey plots.

While this species may also benefit from periodic burns, the population within the study area appears to be doing well and we estimate its viability score at AB and its PS value at 0.8.

Viability Assessment of the Dry-Xeric Forests and Woodlands. Considering only the species actually recorded in the survey, the number that are expected to survive over the coming thirty-year period is calculated by summing their PS values, as follows:

Species	PS
Juniperus virginiana	0.75
Pinus echinata	0.75
Quercus stellata	0.60
Quercus marilandica	0.50
Vaccinium tenellum	0.75
Vaccinium pallidum	0.50
Vaccinium stamineum	0.80
Total	**4.65**
Average	**0.66**

Unrecorded Species. Other vascular plant species that inhabit Dry-Xeric Forests and Woodlands and that have been recorded in Orange and/or Durham Counties include the following species:

Castanea pumila
Viburnum rufidulum
Hieracium venosum (GBIF record from the site)
Hypericum hypericoides (GBIF record from the western side of Hollow Rock)
Sericocarpus caespitosus
Chrysopsis mariana
Solidago pinetorum
Brickellia eupatorioides
Pseudognaphalium helleri

Additionally, Scarlet Oak (*Quercus coccinea*) was observed within the study area but was not found in the survey plots and a species of *Hypericum* was observed within a couple of the plots but not identified to species. Giving these two species as well as *Hieracium* a viability rank of E and PS values of 0.5 but giving the rest PS values of zero, the Expected Number of Survivals is now raised to 6.2 but the Average PS drops to 0.36.

Whereas the habitat at this site seems fairly high in quality for the species that actually occur at this site, its quality for the members of this habitat recorded over the state overall appears to be quite low. Most of the missing species appear to be fairly sparsely distributed in the vicinity of Hollow Rock, but otherwise would be expected to occur there. No common denominator in terms of habitat factors appears to distinguish this set of species from the ones that were recorded.

Rich Upland Hardwood Forests

Recorded Species:
Fraxinus americana + biltmoreana
Carya carolinae-septentrionalis
Cercis canadensis
Ostrya virginiana
Viburnum rafinesqueanum
Dichanthelium boscii

Species belonging to this habitat occur primarily in upland areas that are underlain by rock formations that are rich in nutrients and are relatively high (more basic) in pH. In the Piedmont, these formations primarily consist of mafic rocks such as diabase, gabbro, and basalt, all of which have similar chemical makeup. While some of these species can occur in floodplains in association with rich alluvial deposits rather than underlying mafic rocks, all of the members of this particular group can cope with some degree of drought and can occur on fairly dry ridge tops.

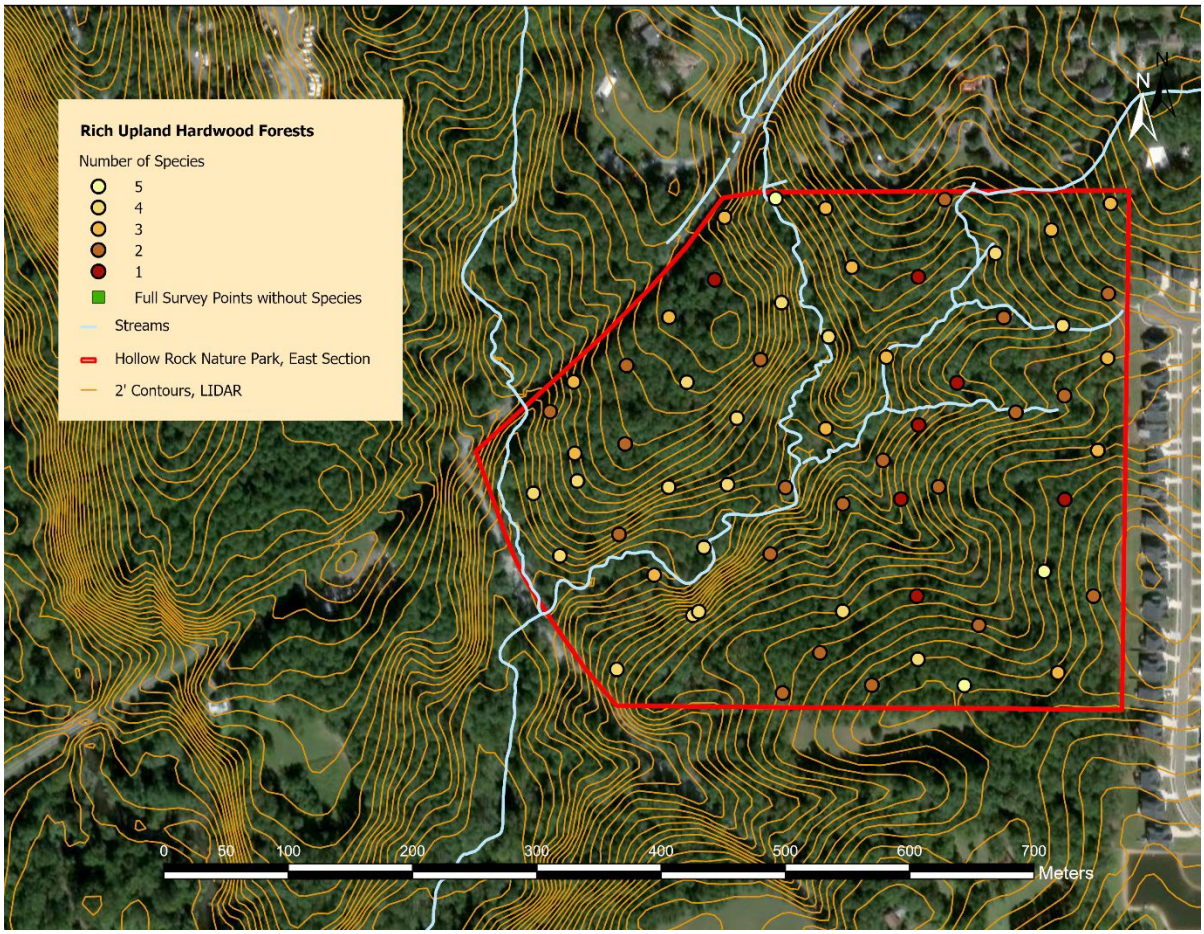


FIGURE 15

As shown in Figure 15, this habitat is well-represented in the study area, with all but two of the full survey plots containing one or more of its species. As was true for the Dry-Xeric Hardwood Forests, this habitat does not appear to be restricted to any particular slope aspect, or to ridges, with some of its species also occurring along the creek terraces. While some concentration might have been expected within the area on the west side of the study area where the diabase dike is located, species belonging to this habitat seem instead to be fairly evenly distributed across the entire site. Although at least some of the species are adapted to growing on the richer montmorillonite clay weathered from mafic rocks, this finding otherwise seems at odds with the description of White Store soils as acidic and nutrient poor.

***Fraxinus americana* (White Ash) and *Fraxinus biltmoreana* (Bilmore Ash).** These two species are very similar in appearance and in their association with upland rather than bottomland forests. Both also require relatively basic, nutrient-rich soils and are not usually found growing in acidic soils. Although both species have been documented within the study area, separating the two species requires examination of the leaves, which were typically out of reach in the few tree-sized specimens that still exist in the study area. Consequently, we treated these two species as a single complex.

Figure 16 shows the distribution of ash within the study area. It also makes a distinction between plots that contain just seedlings and transgressives versus those that have taller saplings or larger trees, or that contain both.

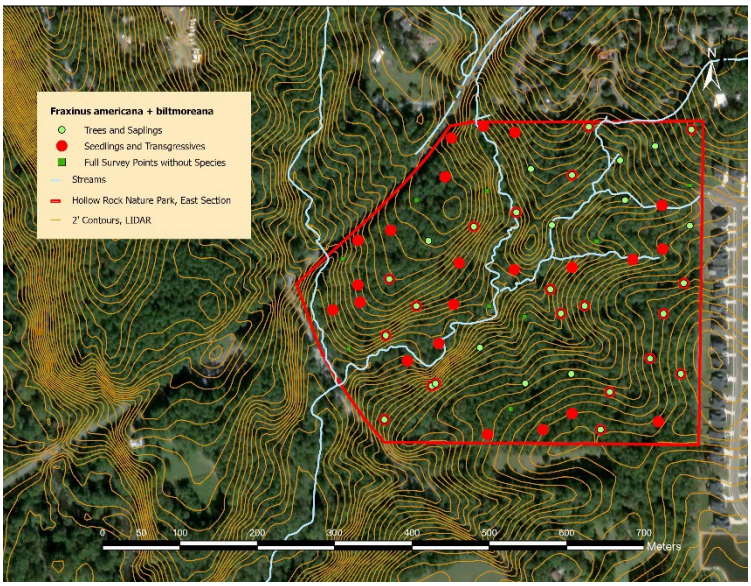


FIGURE 16

Although 54 (88%) of the plots contain ashes, 42 (69%) contain only seedlings or transgressives (1-3' tall with multiple twigs or branches). Due to the depredations of the exotic Emerald Ash Borer, mature trees are dying out across the entire state. Within the study area, we recorded dead snags in only 5 of the plots but both snags and fallen logs were encountered widely throughout the area. Unless the borer is brought under control before this last cohort reaches maturity – when the beetles begin their attack – this may be the last cohort of these species.

As a reproducing population, we rate the viability of the ashes as between a D level (poor viability) and Moribund, a level that we have added to the occurrence ranks used by NHP. The resulting PS value is 0.35 over the next thirty years. If the ashes start dying off sooner than that as they get larger, then the PS value may be significantly over-estimated. Periodic re-assessments will be necessary.

***Carya carolinae-septentrionalis* (Southern Shagbark Hickory).** This species is considered one of the hallmark species of upland forests growing on diabase or other mafic rocks. At the Mason Farm Preserve in Orange County, this species is one of the most frequent and largest trees growing on the extensive diabase dike found at that site. Within the Hollow Rock study area, however, it is fairly scarce – we recorded only two mature trees in our plots, plus one sapling that we tentatively identified as this species. All were widely separated and no seedlings or transgressives were observed.

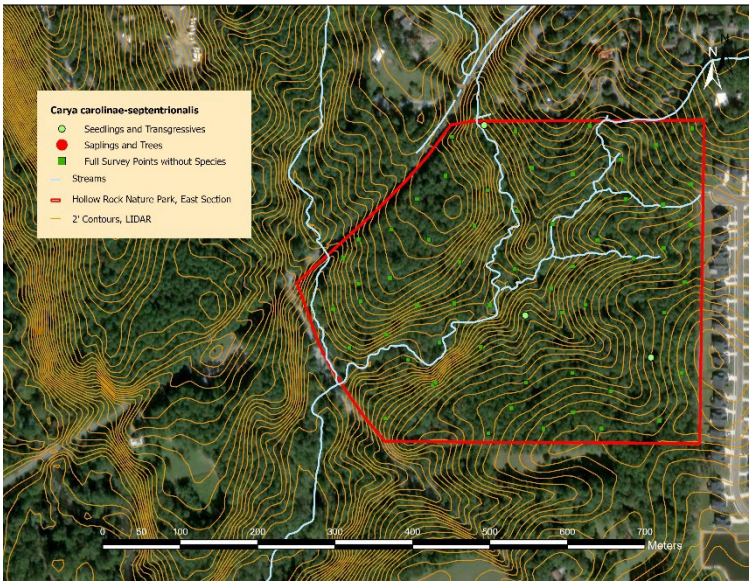


FIGURE 17

Due to the small number of individuals and with no evidence of strong reproductive success, we rate the viability of this population at the CD level, with a PS score of 0.5 over the next thirty years.

***Cercis canadensis* (Eastern Redbud).** Redbuds are another characteristic species of upland forests growing on mafic or otherwise moderately rich substrates. They are considered to be shade tolerant (Dickson, 1990), and therefore do not require disturbances to the canopy in order to maintain their populations.

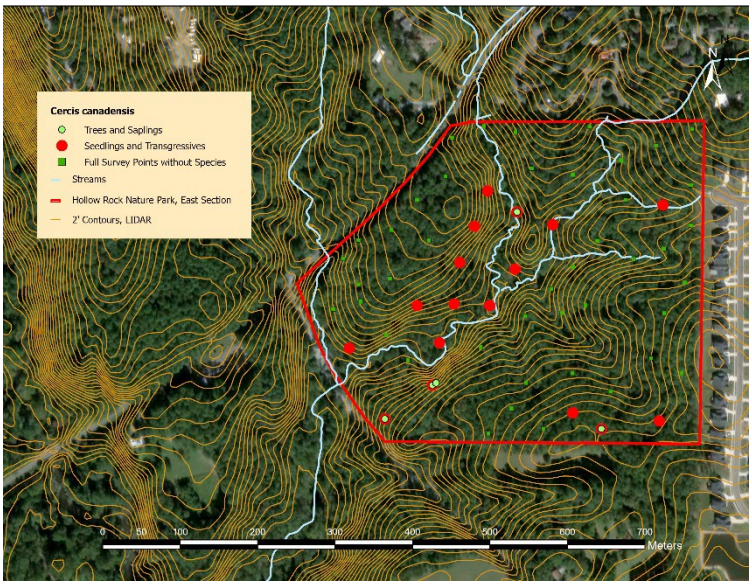


FIGURE 18

This species occurs moderately widely within the study area, but primarily on the slopes and creek terraces. We recorded tree-sized individuals in only five (8%) of the plots and seedlings/transgressives in only 17 (28%).

We rate its viability as a reproducing population at C (Fair), producing a PS value of 0.70 over the next thirty years.

***Ostrya virginiana* (American Hop-hornbeam).**

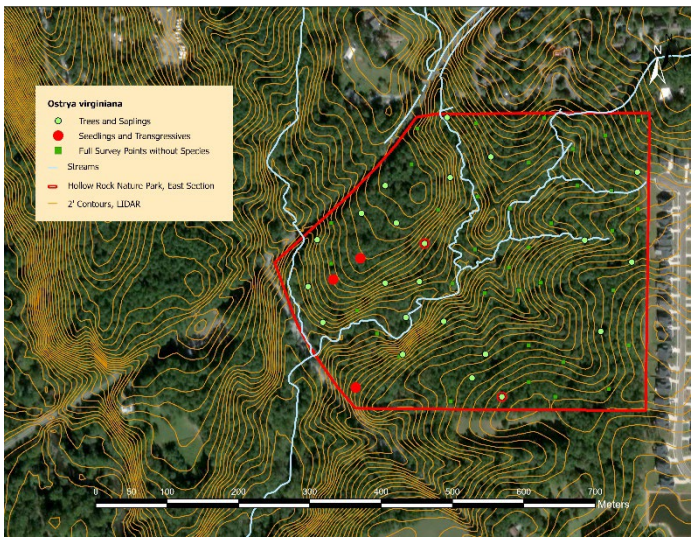


FIGURE 19

Hop-hornbeam is another small tree associated with mafic or other habitats with fairly rich, fairly high pH habitats, occurring primarily in dry-mesic uplands but also to some degree in floodplains (LeGrand et al., 2024). It is shade tolerant and reproduces well under climax conditions; it does not require canopy-opening disturbances to reproduce (Metzgar, 1990).

This species is more widely distributed in our samples than Redbud, occurring in 26 (43%) of our plots and primarily as mature trees rather than as seedlings/transgressives. We estimate the viability score for this species at BC and the corresponding PS value at 0.75 over the next thirty years.

***Viburnum rafinesquianum* (Downy Arrowwood).** This species, like the species just described, is an understory shrub that once formed dense, head-high thickets in many hardwood stands within our region, usually on fairly rich soils. Due largely, if not completely, to the depredations of the expanding deer herd, those thickets have disappeared over large areas and within the study area. Most individuals are now less than 6" in height (as shown in the photograph below). In many cases, the existence of stripped petioles shows where deer have browsed the foliage.

This species is still widespread and fairly common across the study area. However, most individuals recorded in our plots were under 1-2' in height. Only one was found that was over 3'

in height, which is still small for this species. One or two others seen outside the plots were at least 4' in height.

As in the case of the ash species, the remaining individuals of this species may never survive to reach maturity

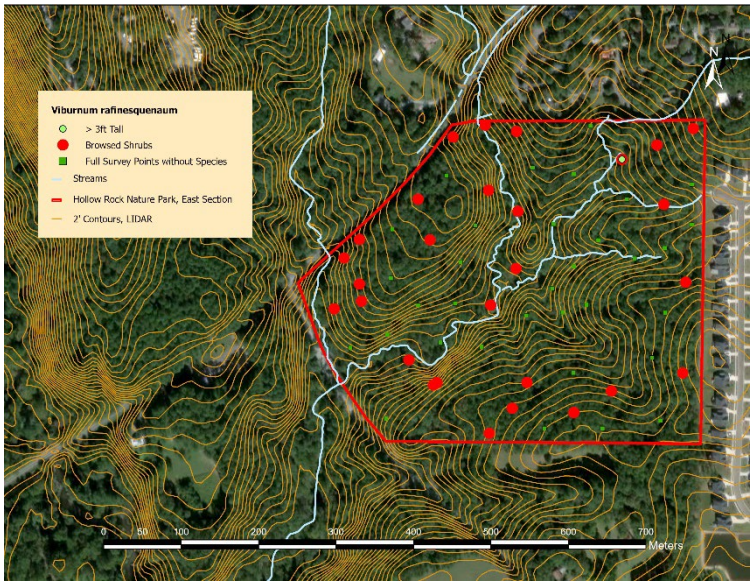


FIGURE 20

and may represent their last cohort within the study area. Consequently, We assess the viability of this occurrence at DM, with only a 0.3 probability of surviving over the next thirty years.

***Dichanthelium boscii* (Bosc's Witchgrass).** This grass (identity confirmed by Bruce Sorrie) is strongly associated with nutrient-rich or mineral-rich soils (LeGrand et al., 2024). Of the few species of grasses observed within the study area, this was by far the most widespread, recorded in 39 (83%) of the survey plots.

This population appears to be fairly vigorous and we estimate its viability score to be AB, resulting in a PS value of 0.8 over the next thirty years.

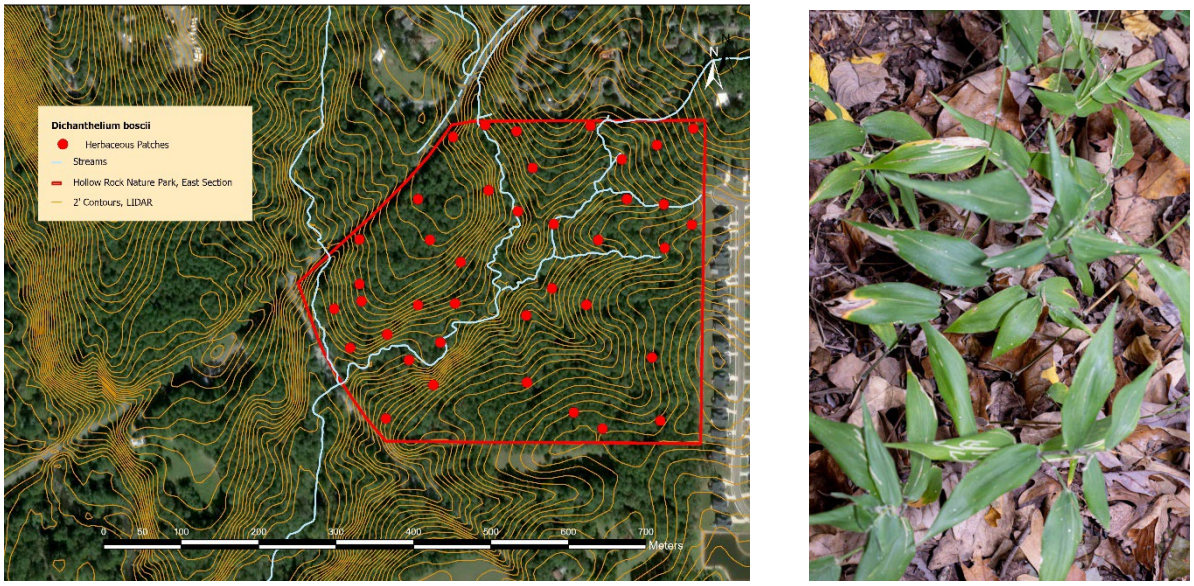


FIGURE 21

Viability Assessment of the Rich Upland Hardwood Forests. Considering only the species actually recorded in the survey, the number that are expected to survive over the coming thirty-year period is calculated as follows:

Species	PS
Fraxinus americana	0.35
Fraxinus biltmoreana	0.35
Carya carolinae-septentrionalis	0.50
Cercis canadensis	0.70
Ostrya virginiana	0.75
Viburnum rafinesqueanum	0.30
Dichanthelium boscii	0.80
Total	**3.75**
Average	**0.54**

The average PS value of 0.54 for this group appears to be substantially lower than the 0.67 found for the Dry-Xeric Hardwoods Forests and Woodlands but is largely due to the inclusion of three species that are imperiled for reasons other than habitat suitability. If the two species of *Fraxinus* and the *Viburnum* are removed, the site average is now 0.61, comparable to what was obtained for the Dry-Xeric Hardwood

Unrecorded Species

The following 13 species occur in rich upland habitats and have been recorded in Durham and Orange Counties. However, they were not recorded in the current survey (none were recorded in GBIF for this site):

Aquilegia canadensis
Borodinia canadensis
Celtis occidentalis
Corylus americana
Cubelium concolor
Eupatorium godfreyanum
Gillenia stipulata
Phaseolus polystachios
Ptelea trifoliata
Senega officinalis
Tilia americana
Tragia urticifolia
Viola palmata

Including the thirteen unrecorded species but retaining the three species with low individual values causes the average relative to state expectations drops to 0.19. Given the supposed acidic nature of Whitestore soils, it may be more surprising that the seven species that were recorded occur within the study area, at least at locations located well-away from the diabase dike. Nonetheless, with the exception of *Carya carolinae-septentrionalis* these species were common throughout the study area, both as mature, reproductive individuals and as seedings/transgressives.

Rich Wet-Mesic Hardwood Forests

Recorded Species
Acer floridanum
Carya ovata
Carya cordiformis
Celtis laevigata
Morus rubra
Ulmus rubra
Menispermum canadense

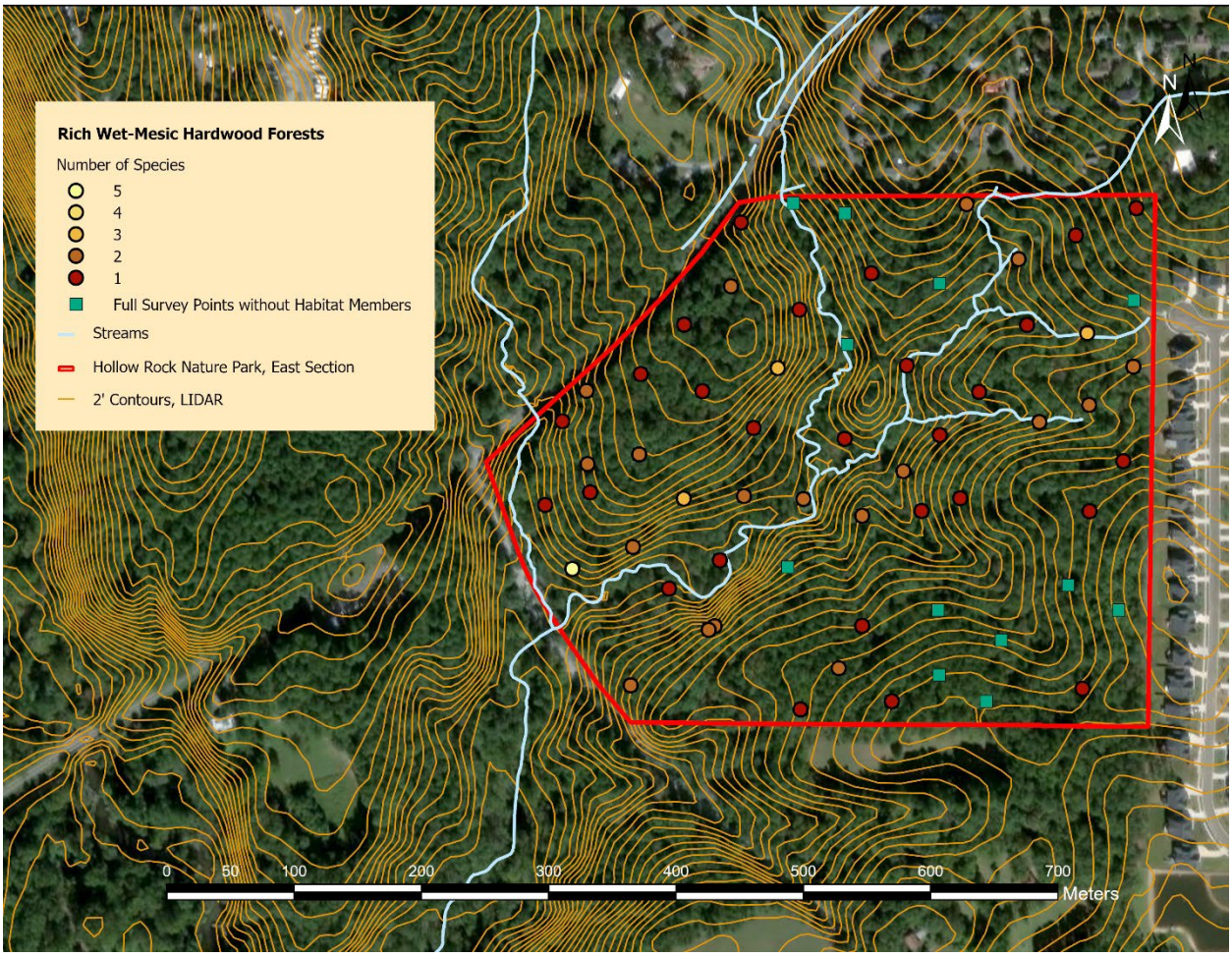


FIGURE 22

Members of this habitat, like the preceding group, grow primarily in areas with nutrient-rich, relatively high pH soils. However, they require more moisture than those of the preceding group and rarely occur on upper slopes or summits. Conversely, this group is tolerant of at least some degree of flooding and can occur out in floodplains.

At least some members of this habitat – mainly Florida Maple and Northern Shagbark Hickory – are found fairly widely across the study area. Most of the remaining species are absent from the broader uplands, showing more of a concentration on the lower slopes or stream terraces.

***Acer floridanum* (Florida Maple).** This is one of the tree species regularly found in brownwater stream and river floodplains but also grows in uplands where the soils are circumneutral (LeGrand et al., 2024). We also checked for the presence of Chalk Maple (*Acer leucoderme*), a species that grows in rich upland sites, but all specimens appeared to have a leaf morphology that is more typical of *floridanum*.

Within the study area, the majority of its occurrences are located along the stream terraces or lower slopes, where both seedlings/transgressives and older individuals occur commonly in the same plots.

Seedlings/transgressives were also observed higher up on the slopes, but may not survive as well as lower down; fewer larger sized individuals were found in those areas.

Most of the tree-sized specimens were only 2-4” in diameter, but there were four that were 5” or larger; the largest was 9” dbh. These sizes appear to be consistent with observations both in North Carolina and elsewhere, where this species grows primarily as an understory tree (Jones, 1990).

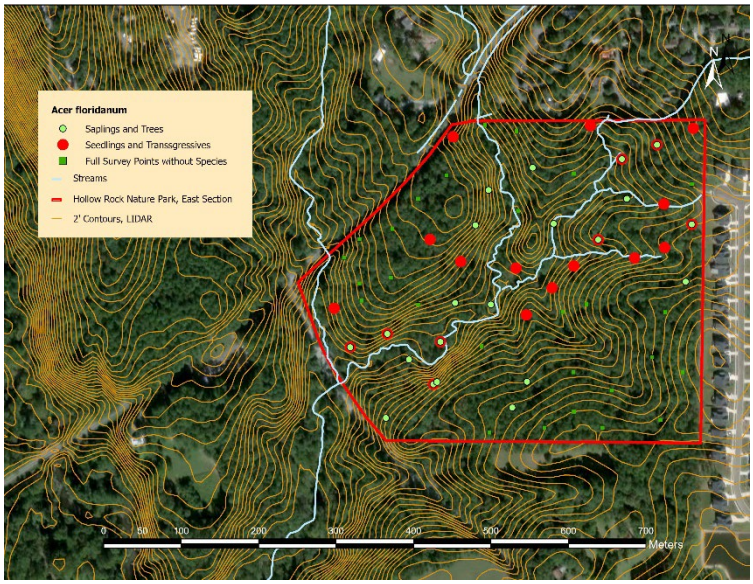


FIGURE 23

This shade-tolerant species appears to be reproducing fairly well within the study area, and this may be a sub-occurrence of the much larger population that extends downstream along New Hope Creek. We consequently estimate the viability score for this species as AB, producing an estimated 0.8 probability of surviving on this site over the next thirty years.

Northern Shagbark Hickory (*Carya ovata*). This is another tree species that is strongly associated with moist, nutrient rich, relatively high pH soils, mainly in brownwater river bottomlands but also on slopes and upland flats where the soils are particularly rich (LeGrand et al., 2024). It was one of the characteristic species of the New Hope Bottomlands sites studied by the NCBP in the 2021-22 multi-taxa survey (Hall et al., 2022) and in a follow-up survey conducted by Hall and Tingley (2023). In the current survey, this species was recorded in 27 (44%) of the survey plots located mainly on the slopes and ridge-tops rather than the creek terraces, a pattern shown by both the tree-sized individuals and the seedlings/transgressives.

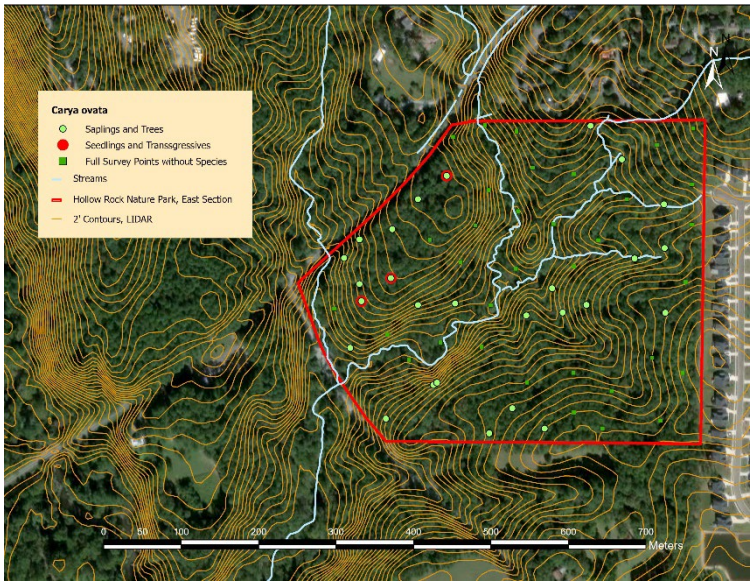


FIGURE 24

This species is intermediate in its shade tolerance: its seedlings can grow in the shade but benefit from openings occurring in the canopy (Graney, 1990). Both large and small individuals were present throughout the site, with a strongly skewed distribution of size classes as shown in Figure 25. This may indicate a fairly recent recovery from a past disturbance event such as a fire.

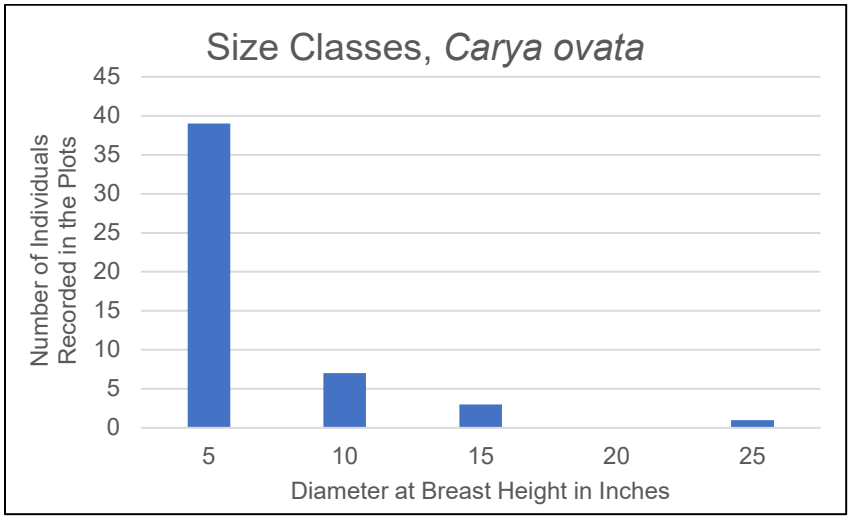


FIGURE 25

As was the case with the Florida Maple, the population within the study area is probably a sub-unit of the much larger occurrence that extends from the upland area of Hollow Rock Park on the west side of Pickett Road and downstream within the floodplain as far as the Jordan Lake Game Land. Consequently, we estimate the viability score for this species as AB, producing an estimated 0.8 probability of surviving on this site over the next thirty years.

***Carya cordiformis* (Bitternut Hickory).** This species is associated primarily with brownwater river bottomlands but also occurs on lower slopes where the soil is also rich, usually underlain with mafic rock formations in the Piedmont. This species is fairly marginal within the study area, recorded in only seven (11%) of the plots, mostly up on the slopes, but with one individual as large as 4" dbh observed on a creek terrace. Seedlings/transgressives were recorded at four sites, two of which also had tree-sized individuals. This indicates that at least some reproduction is taking place within the study area. Nonetheless, we estimate its viability score at C, with a 0.6 probability of surviving over the next thirty years.

***Ulmus rubra* (Slippery Elm).** This species is more common on rich, mesic slopes than bottomlands, but was recorded in only three (5%) of the plots in the survey. All three had saplings or larger trees, the largest of which was 9" dbh. Only one of these plots had any seedlings/transgressives. We rate this population as CD, with an estimated 0.50 probability of surviving over the next thirty years.

***Celtis laevigata* (Sugarberry).** Recorded at a single point near the confluence of the two main creeks draining the study area. This bottomland species appears to be only marginal within the study area, rating only a D level occurrence and an estimated 0.4 probability of surviving there over the next thirty years.

***Morus rubra* (Red Mulberry).** This species is associated with rich, mesic forests, but can occur more widely, due to the dispersal of its seeds by birds. We recorded one tree, 5" dbh, in the survey, along with one seedling. Although this indicates that this species has a very low density within the study area, this is typical for this species, which usually occurs as scattered individuals (Lamson, 1990). While it is likely to persist at this site, if only by occasional dispersal into the study area, we rate its occurrence there as only a CD in terms of viability, with an estimated 0.50 probability of surviving over the next thirty-year period.

***Menispermum canadense* (Canada Moonseed).** This herbaceous vine occurs at scattered locations in the New Hope Creek bottomlands but we recorded it at only two plots in the Hollow Rock study area. We estimate this species has a CD viability rating, with an estimated 0.50 probability of surviving over the next thirty-year period.

Viability Assessment of the Rich Upland Hardwood Forests. Considering only the species actually recorded in the survey, the number that are expected to survive over the coming thirty-year period is calculated as follows:

Species	PS
Acer floridanum	0.80
Carya ovata	0.80
Carya cordiformis	0.60
Ulmus rubra	0.50
Celtis laevigata	0.40
Morus rubra	0.50

Species	PS
Menispermum canadense	0.50
Total	**4.20**
Average	**0.60**

This average for species found on the study area is lower than that for the Dry-Xeric Hardwood Forests and Woodlands and lower for the non-habitat-imperiled species in the Rich Upland Hardwood Forests. Only two species, *Acer floridanum* and *Carya ovata*, appear to be doing well at this site.

Unrecorded Species

The following 69 species occur in rich bottomland and lower slope habitats and have been recorded in Durham and Orange Counties. However, they were not recorded in the current survey:

Aconitum uncinatum
Actaea pachypoda
Actaea racemosa
Adiantum pedatum
Aesculus sylvatica
Amauropelta noveboracensis
Amsonia tabernaemontana
Arisaema dracontium
Aruncus dioicus
Asarum reflexum
Asimina triloba
Athyrium asplenioides
Bromus pubescens
Calycanthus floridus
Cardamine concatenata
Cardamine diphylla
Cardamine dissecta
Cardamine douglassii
Carex blanda
Carex crebriflora
Caulophyllum thalictroides
Chaerophyllum procumbens
Chasmanthium latifolium
Circaea canadensis
Claytonia virginica
Collinsonia canadensis
Collinsonia tuberosa
Coreopsis tripteris
Corydalis flavula
Cryptotaenia canadensis
Cypripedium parviflorum
Dicentra cucullaria
Dioscorea quaternata
Elymus hystrix
Erythronium americanum
Euphorbia obtusata
Galearis spectabilis
Geranium maculatum
Geum canadense
Geum virginianum
Hylodesmum glutinosum
Iris cristata
Juglans nigra
Laportea canadensis
Leersia virginica
Lindera benzoin
Luzula acuminata
Nanopanax trifolius
Panax quinquefolius
Persicaria virginiana
Phegopteris hexagonoptera
Phryma leptostachya
Poa cuspidata
Podophyllum peltatum
Ranunculus hispidus
Ranunculus micranthus
Sanguinaria canadensis
Scrophularia marilandica
Smallanthus uvedalia
Smilax herbacea
Smilax hispida
Staphylea trifolia
Steironema ciliatum
Thaspium barbinode
Tiarella cordifolia
Viburnum prunifolium
Viola eriocarpa
Vitis labrusca
Vitis riparia

Some of these species are spring ephemerals and could have been missed due to the survey being conducted during the late spring and summer. Several, in fact, were observed along the slope above New Hope Creek within the western portion of the Hollow Rock Preserve, including *Claytonia virginica, Dicentra cucullaria,* and *Erythronium americanum.* However, we estimate that at least the following 22 of the above species should have been visible during the survey, including *Adiantum pedatum, Aesculus sylvatica, Arisaema dracontium, Asarum reflexum, Calycanthus floridus, Chasmanthium latifolium, Geranium maculatum, Iris cristata, Juglans nigra, Laportea canadensis, Lindera benzoin, Panax quinquefolius, Podophyllum peltatum, Sanguinaria canadensis, Smallanthus uvedalia, Smilax herbacea, Smilax hispida, Staphylea trifolia, Tiarella cordifolia, Viburnum prunifolium, Vitis labrusca,* and *Vitis riparia.*

If we include the 22 species mentioned above as detectable during the survey period, the average PS value drops to 0.14. As in the previous habitat associated with rich soils, this low value seems reasonable for a site with predominantly acidic soils. It is more the abundance of Florida

Maples and Northern Shagbarks across the study area that needs explaining than the absence of other basophilic species.

General Wet Hardwood Forests

Recorded Species
Carpinus caroliniana
Quercus phellos
Uvularia sessifolia

Members of this habitat are associated mainly with floodplains, but can also occur to some extent in uplands where there is a high water-table.

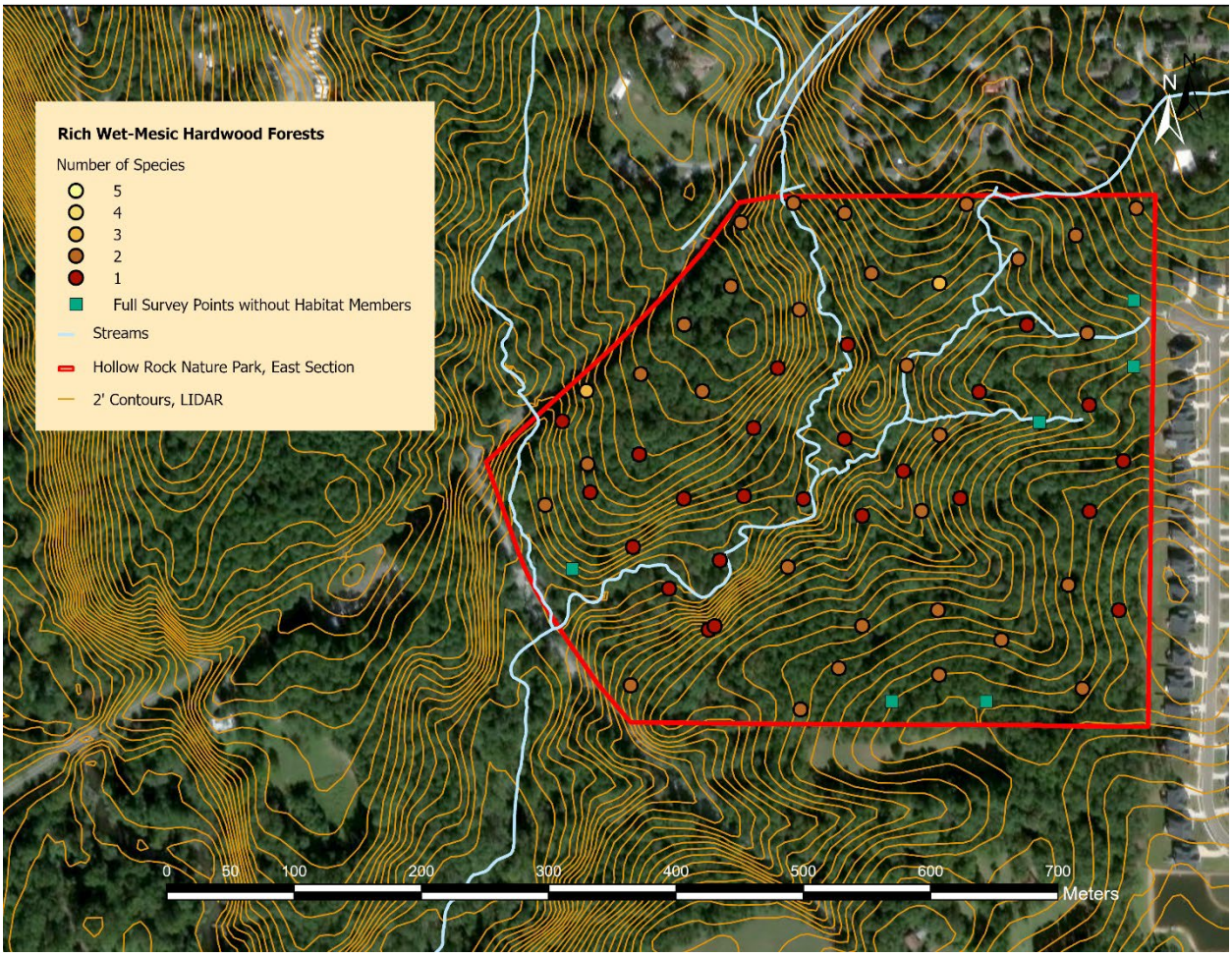


FIGURE 26

***Carpinus caroliniana* (American Hornbeam).** This species is strongly associated with bottomlands, including both blackwater and brownwater. It also occurs on lower slopes, particularly where the soils are fairly rich (LeGrand et al., 2024). Within the study area, however, it was recorded throughout the site, including well up the slopes where it was recorded as both mature trees and as seedlings/transgressives.

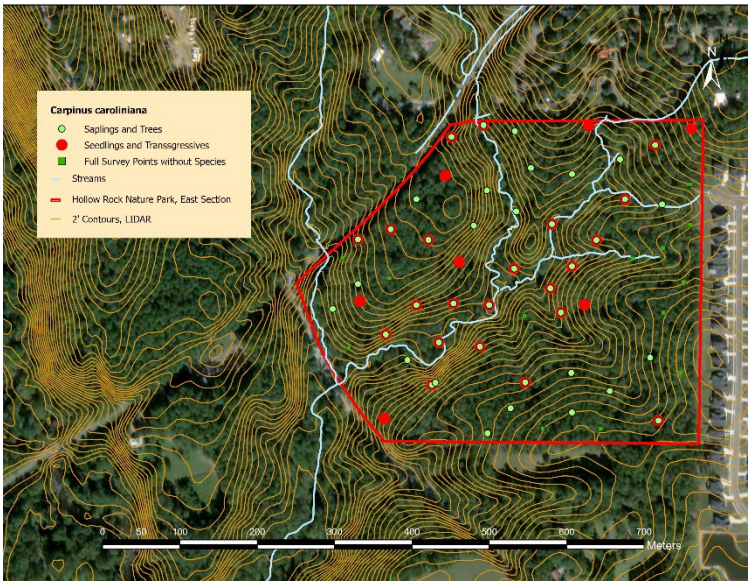


FIGURE 27

Carpinus is a shade-tolerant species and appears to be reproducing quite well within the study area. Given its widespread occurrence, abundance, strong evidence of reproduction, and connection to a much larger population along New Hope Creek, we estimate the viability of this occurrence as AB, conferring a 0.8 probability of its surviving over the next thirty years.

***Quercus phellos* (Willow Oak).** This is another species that is a typical member of floodplains, including blackwater as well as brownwater. It also grows in upland depressions or even hardpan barrens, especially where the soils are nutrient-rich and relatively high in pH (LeGrand et al., 2024).

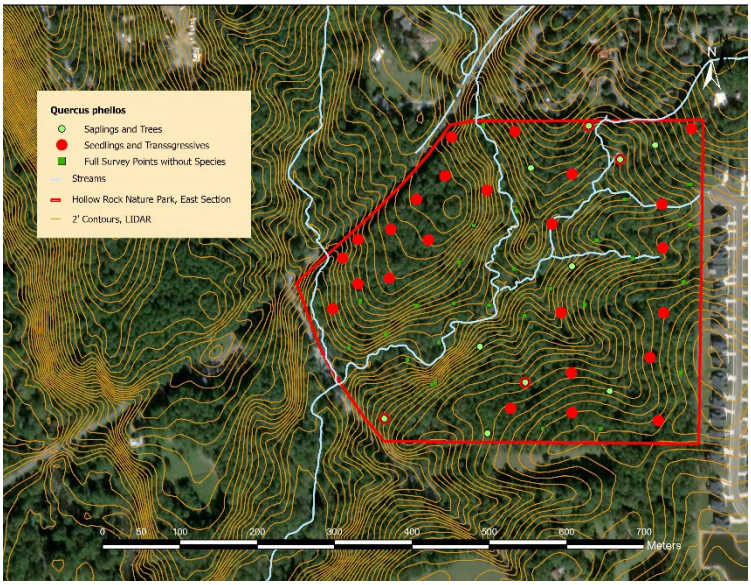


FIGURE 28

While this species was common throughout the study area, it was present primarily as immature specimens: saplings were recorded at a number of sites but only one specimen was found that was as large as 2” in dbh. Surprisingly, almost all of our records come from sites well up on the slopes and just a few on the stream terraces.

Although there is clear evidence that reproduction is taking place, there is no evidence that seed-producing trees exist within the study area itself. Likewise, there is no evidence that individuals are surviving to reach maturity within the site. Without any indication that this is a successfully reproducing population, the occurrence rates only a CD viability score. Even though seeds may continue to arrive within the study area – possibly all produced outside – the probability of this occurrence persisting on its own appears to be low, only around 0.5

***Uvularia sessilifolia* (Sessile-leaf Bellwort).** In North Carolina, this bellwort grows primarily in brownwater bottomlands but can also occur on moist forested slopes, including acidic monadnocks (Schafale, 2023). Within the study area, it appears to be sparsely distributed, recorded in only six (10%) of the plots and usually only as single individuals.

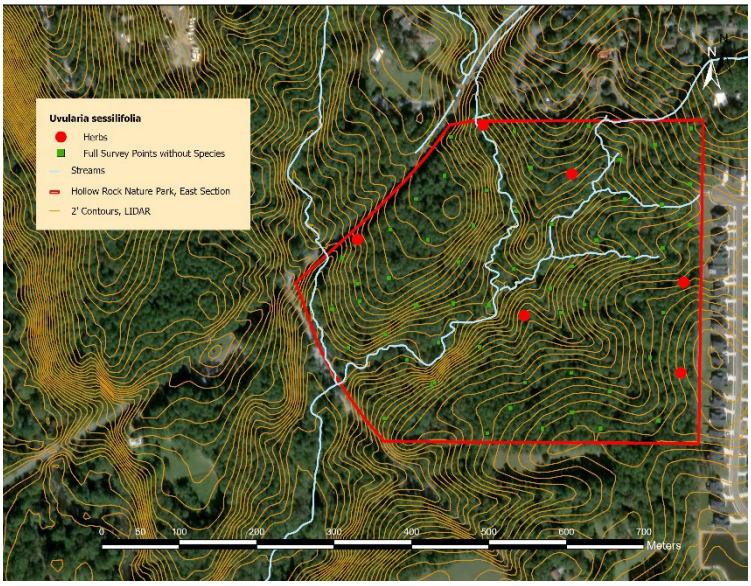


FIGURE 29

Although we did not see any individuals in either flower or fruit – which appears to be fairly common observations (LeGrand et al., 2024), this species seems likely to be reproducing within the study areas. Given its very sparse density, however, this occurrence seems to merit only a CD viability score, with only a 0.50 probability of surviving over the next thirty years.

Viability Assessment of General Wet Hardwood Forests. Considering only the species actually recorded in the survey, the number that are expected to survive over the coming thirty-year period is calculated as follows:

Species	PS
Carpinus caroliniana	0.80
Quercus phellos	0.50
Uvularia sessifolia	0.50
Total	**1.80**
Average	**0.60**

Unrecorded Species

The following species generally occur in bottomlands and adjoining slopes and have been recorded in Durham and Orange Counties. However, they were missed in the current survey:

Amphicarpaea bracteata
Arisaema triphyllum
Betula nigra
Cardamine angustata
Carex debilis
Carex gracillima
Carex pigra
Erythronium umbilicatum
Eurybia divaricata
Gonolobus suberosus
Lactuca floridana
Passiflora lutea
Quercus pagoda

Trillium catesbyi
Viola affinis
Vitis baileyana
Vitis simpsonii
Zephyranthes atamasco

Some of these species are spring ephemerals and were probably dormant by the time the survey was conducted. Others, such as the Carex and Viola species, require flowers or seeds in order to identify them and were recorded only to the generic level in the survey. Others, however, are unlikely to have been overlooked if present, including *Amphicarpaea bracteata*, *Arisaema triphyllum, Betula nigra, Gonolobus suberosus, Lactuca floridana, Passiflora lutea*, *Quercus pagoda, Trillium catesbyi, Vitis baileyana, Vitis simpsonii,* and *Zephyranthes atamasco*. If these 11 species are included in the viability analysis, the average PS value drops to 0.13.

For an essentially upland site, this low value seems more reasonable than the relatively high average PS calculated based only on the observed species. However, that value itself is due mainly to the commonness of American Hornbeam within the study area, which is what appears to be the anomaly with regard to this habitat. Willow Oaks are also common, but in their case they are present solely as seedlings or at most young saplings rather than as mature trees.

General Hardwood Forests

Recorded Species:

Acer rubrum
Bignonia capreolata
Carya glabra
Carya tomentosa
Elephantopus carolinianus
Euonymus americanus
Fagus grandifolia
Galium circaezans
Galium uniflorum
Hepatica americana
Hexastylis arifolia
Liriodendron tulipifera
Maianthemum racemosum
Nyssa sylvatica
Oxydendrum arboreum
Quercus alba
Quercus falcata
Quercus rubra
Quercus velutina
Ulmus alata
Viburnum acerifolium

The species that compose this habitat are hardwood forest generalists, tolerant of or requiring shaded conditions, but both uplands and bottomlands are occupied and they occur across a wide range of moisture regimes and soil types. Consequently, they are among the most wide-ranging species across the state. None stand out as having any particular conservation concern.

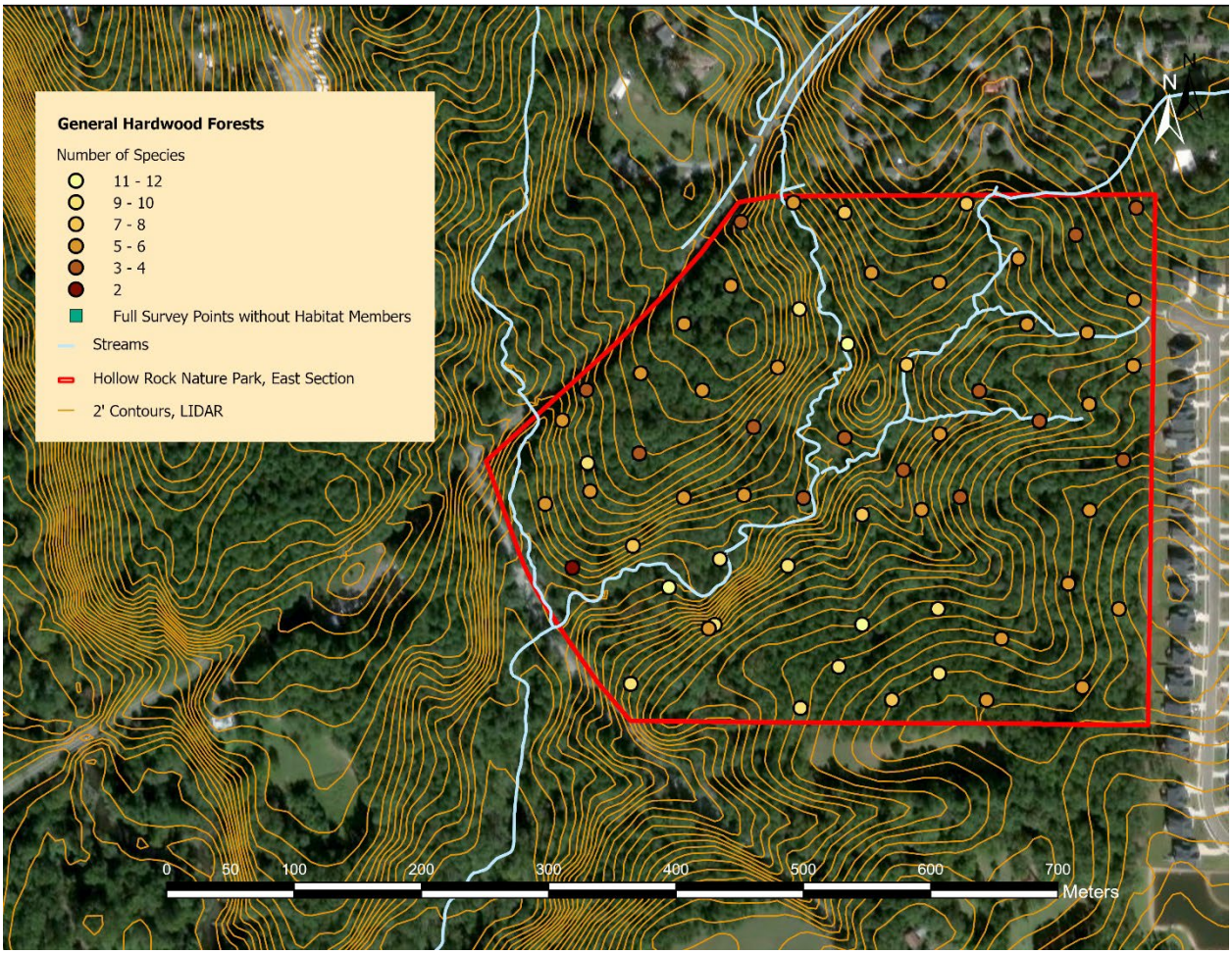


FIGURE 30

As shown in Figure 30, these species are well-represented across the study area, with each survey plot containing one or more individuals. White Oak was particularly abundant, occurring in 54 (88%) of the plots and representing some of the largest trees as well as the most abundant seedlings and transgressives. Instead of using species accounts to describe the presence of each of the species in this group individually, the following table summarizes both their representation and viability within the study area. Note that two species not recorded in the survey plots – *Hamamelis virginiana* and *Nestronia umbellula* – are included in the analysis.

Species	Growth Form Proportion of Survey Plots			Viability Score	Probability of Survival
	Seedlings/ Transgressives	Saplings/ Trees	Herbs/Shrubs /Vines		
Quercus alba	62%	77%		A	0.90
Carya tomentosa	49%	67%		AB	0.85
Acer rubrum	26%	46%		B	0.80
Quercus velutina	21%	44%		BC	0.70
Quercus falcata	18%	23%		BC	0.70
Ulmus alata	13%	23%		C	0.60
Quercus rubra	13%	16%		C	0.60
Fagus grandifolia	5%	18%		C	0.60
Carya glabra	16%	13%		C	0.60
Nyssa sylvatica	10%	15%		C	0.60
Oxydendrum arboreum	0%	5%		D	0.40
Liriodendron tulipifera	2%	2%		D	0.40
Viburnum acerifolium	3%			D	0.40
Euonymus americanus			62%	AB	0.85
Galium uniflorum			26%	BC	0.70
Galium circaezans			21%	BC	0.70
Maianthemum racemosum			15%	C	0.60
Hexastylis arifolia			13%	C	0.60
Elephantopus carolinianus			11%	CD	0.40
Hepatica americana[4]			2%	D	0.40
Bignonia capreolata	2%			E	0.50
Total					**12.9**
Average for Observed Species					**0.61**
Hamamelis virginiana				Unrecorded	0.00
Nestronia umbellula				Unrecorded	0.00
Average for all Expected Species					**0.56**

The site average PS is in line with the other habitats considered so far, but the average for all expected species is much higher, due to the fact that only two were unrecorded in the survey.

[4] While Hepatica was rare over the study area as a whole, it was quite common growing on the top of the diabase dike.

General Forests

Recorded Species:

Asimina parviflora
Asplenium platyneuron
Chionanthus virginicus
Cornus florida (= Benthamidia florida)
Hexastylis lewisii
Ilex decidua
Ilex opaca
Liquidambar styraciflua
Lonicera sempervirens
Mitchella repens
Muscadinia rotundifolia
Parthenocissus quinquefolia
Pinus taeda
Polystichum acrostichoides
Smilax bona-nox
Smilax glauca
Smilax rotundifolia
Tipularia discolor

Members of this habitat are herbaceous, shrubby, or viny species that occupy a wide range of forest and woodland habitats, including those with the canopy composed of either hardwoods or conifers or both. Soil type and moisture regime also vary widely across their occurrences.

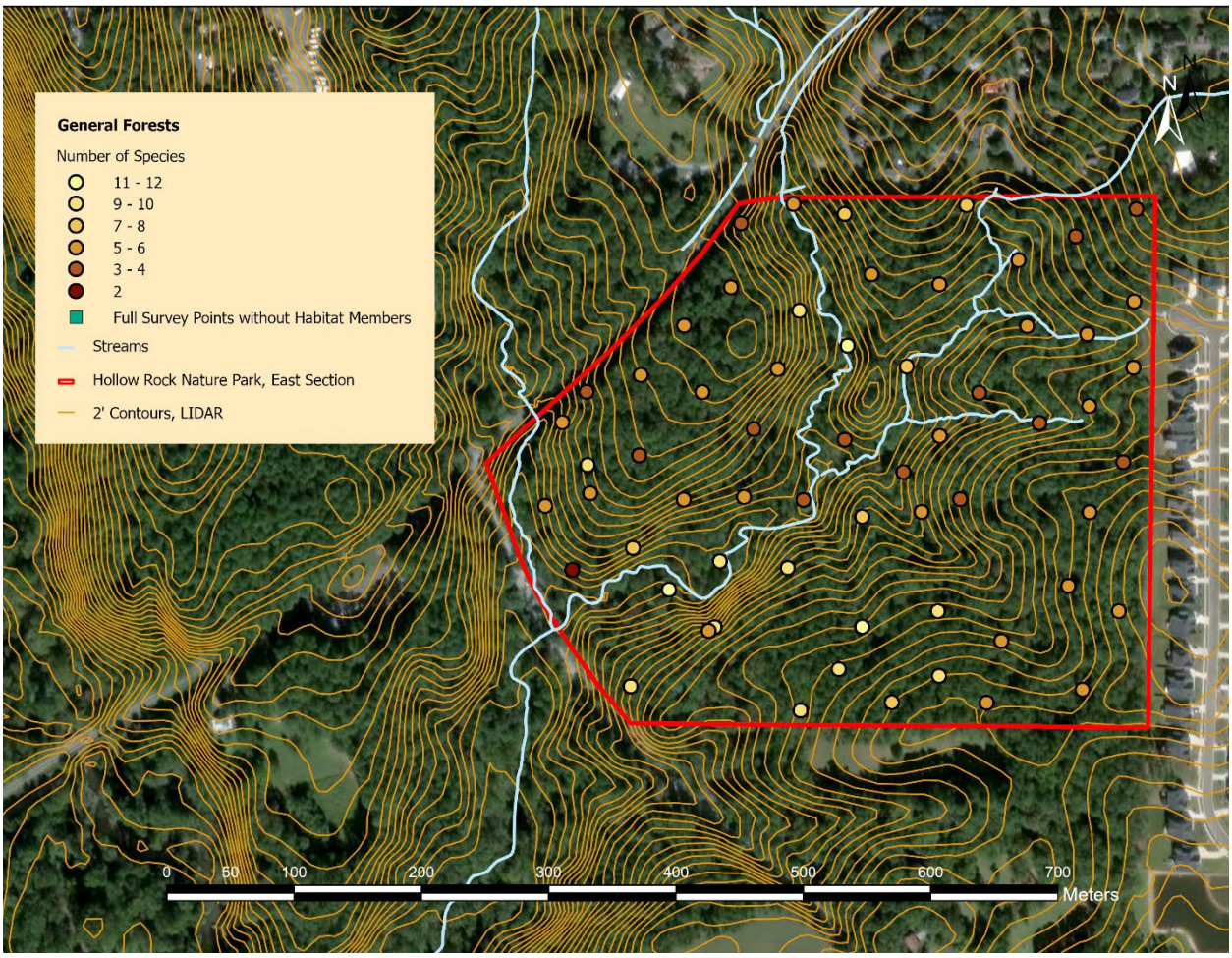


FIGURE 31

Some of the species in this group, such as Muscadine and the Smilax species, are some of the most numerous and widespread in the state. Others, however, are much more restricted in both numbers and distribution. Three of these are treated below in more detail.

***Hexastylis lewisii* (Lewis's Heartleaf).** This clonal species is ranked as G3S3 by the Natural Heritage Program and its status is monitored as a Watch List species. Patches were recorded at four of the full survey points and at one additional site along the trail. All are located on the slopes or floodplain terraces bordering the creeks that run through the study area, habitats that are typical of this species. It also favors acidic soils and appears to be well-adapted to making use of sites underlain by montmorillonite clays, at least those weathered from felsic parent rock, as is the case here.

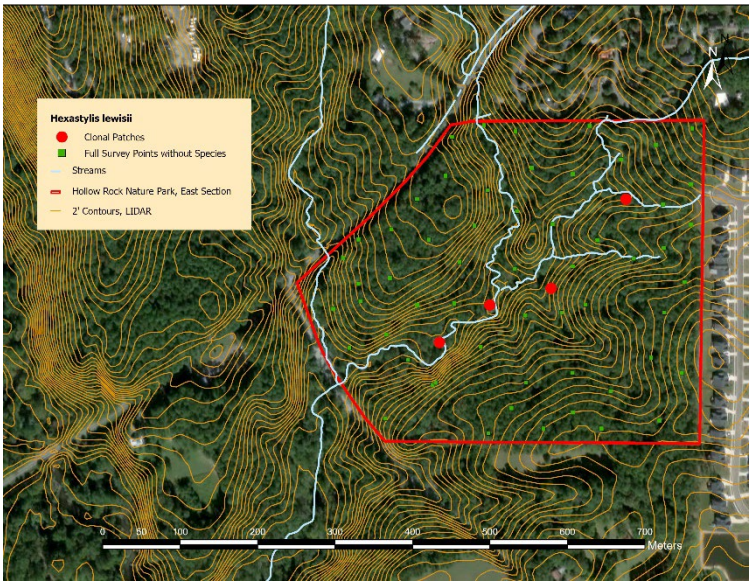


FIGURE 32

This population appears to be vigorous and given its protection from direct development, this occurrence would normally be considered highly viable, with only a very low probability of extirpation. However, it also appears to be extremely isolated and not large enough in itself for any portion to survive a given severe disturbance event; i.e., there is little chance of recovery by recolonization from areas escaping the effects of the disturbance. Given the likely increase in droughts and possibly wild fires, there is at least some probability of extirpation of this population over the next thirty years. Combining this set of factors, we rate this occurrence as having an AC viability score. Expressed numerically, it has an estimated 0.75 probability of surviving over the next thirty years.

***Chionanthus virginicus* (Fringe Tree).**

Like the ash species, the Emerald Ash Borer is decimating populations of this species. Although Fringe Trees are still present over much of this site, almost all of their records within the survey plots represent seedlings or transgressives.

If no effective controls are found to combat the infestation of the Emerald Ash Borer – or if it does not die off as the result of its depredations of its sole host plants – then the immature specimens currently present on the study area may represent the last cohorts of these species. Coupled with increased drought and risk of fire, we consider the occurrences of these species within the preserve to have at best a DM viability score, with an estimated 0.30 probability of surviving over the next thirty years.

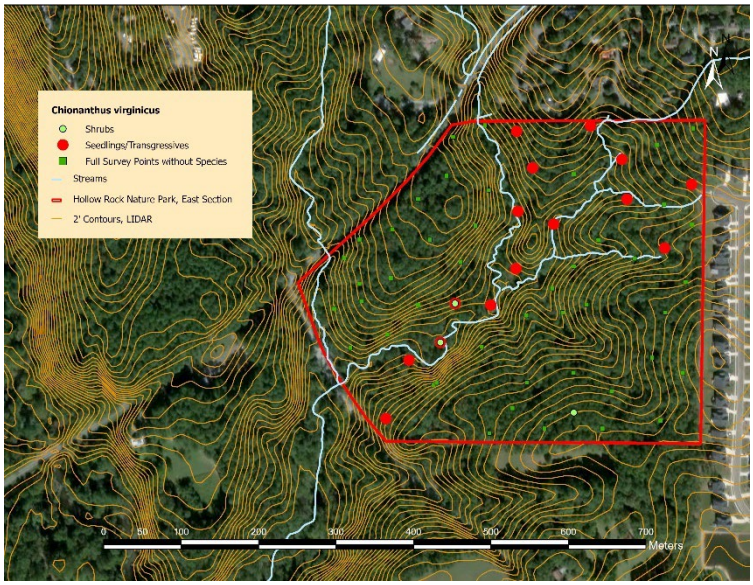


FIGURE 33

***Asimina parviflora* (Dwarf Pawpaw).** Unlike the Common Pawpaw (*A. triloba*), which typically occurs in large bottomland populations, this primarily upland species usually occurs as widely scattered individuals. Coupled with its generally short stature, it is frequently overlooked, but fairly common within the Piedmont and Coastal Plain (LeGrand et al., 2024).

This species was recorded at 12 of the full survey plots, as well as at two of the selective survey points; this density appears to be fairly typical for this species; a similar population exists at the Mason Farm Preserve on the diabase dike that runs along its western edge.

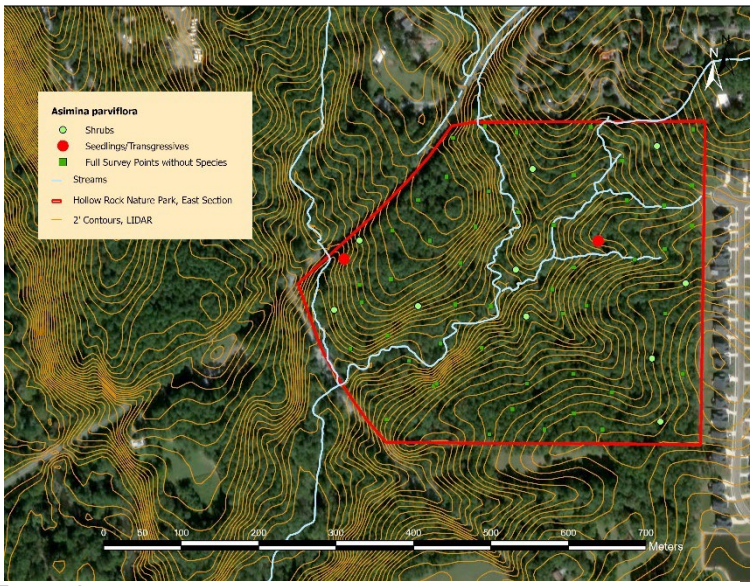


FIGURE 34

Seedlings/transgressives were recorded at two of these points, but none of the larger specimens appeared to have any fruit. Given at least some evidence for reproduction, plus a fairly normal population distribution, the viability score for this species is set at AB, giving it a 0.85 probability of its surviving over the next thirty years.

Viability scores for the rest of the species, along with the combined probability estimates are given in the following table:

Species	Growth Form Proportion of Survey Plots			Viability Score	Probability of Survival
	Seedlings/ Transgressives	Saplings/ Mature Trees	Herbs/Shrubs/Vines		
Liquidambar styraciflua	25%	46%		AB	0.85
Cornus florida (= Benthamidia florida)	8%	15%		C	0.60
Ilex decidua	2%	5%		D	0.40
Ilex opaca	7%	5%		D	0.40
Pinus taeda	0%	5%		D	0.40
Asimina parviflora	3%		16%	AB	0.85
Muscadinia rotundifolia			93%	A	0.90
Tipularia discolor			69%	A	0.90
Parthenocissus quinquefolia			54%	A	0.90
Smilax glauca + rotundifolia			44%	AB	0.85
Mitchella repens			33%	AB	0.85
Polystichum acrostichoides			21%	B	0.80
Smilax bona-nox			18%	B	0.80
Asplenium platyneuron			10%	C	0.60
Hexastylis lewisii[5]			7%	AB	0.85
Lonicera sempervirens			3%	BC	0.70
Chionanthus virginicus			2%	DM	0.30
Total					**11.95**
Average for Observed Species					**0.70**
Botrypus virginianus			Unrecorded		0.00
Pyrola americana			Unrecorded		0.00
Sanicula canadensis			Unrecorded		0.00
Average for All Expected Species					**0.60**

This group of generalists has a much higher average PS value for observed species than those of any of the previously considered habitat. It also has the highest average PS value at the state level, reflecting that very few of the expected species were not recorded in this survey.

[5] This species was found in only a few plots but was abundant within each of them.

Exotic Invasives

Recorded Species

Albizia julibrissin
Elaeagnus pungens
Ligustrum sinense
Lonicera japonica
Lonicera maackii
Microstegium vimineum
Nandina domestica
Rosa multiflora
Youngia japonica

Compared to many natural areas, the study area is not heavily over-run by invasive species. There are, however, six such species that were recorded in this survey, including several, such as Japanese Stilt Grass, Chinese Privet, and Japanese Honeysuckle that have the potential for taking over large areas, particularly following disturbances. As shown in Figure 32, these species are currently found mainly along the creeks through the center of the tract and along the edges. One area where they are currently found only in low numbers is along the eastern side of the preserve. However, this area has recently been developed and is likely to be a major source of invading species as well as other adverse edge effects.

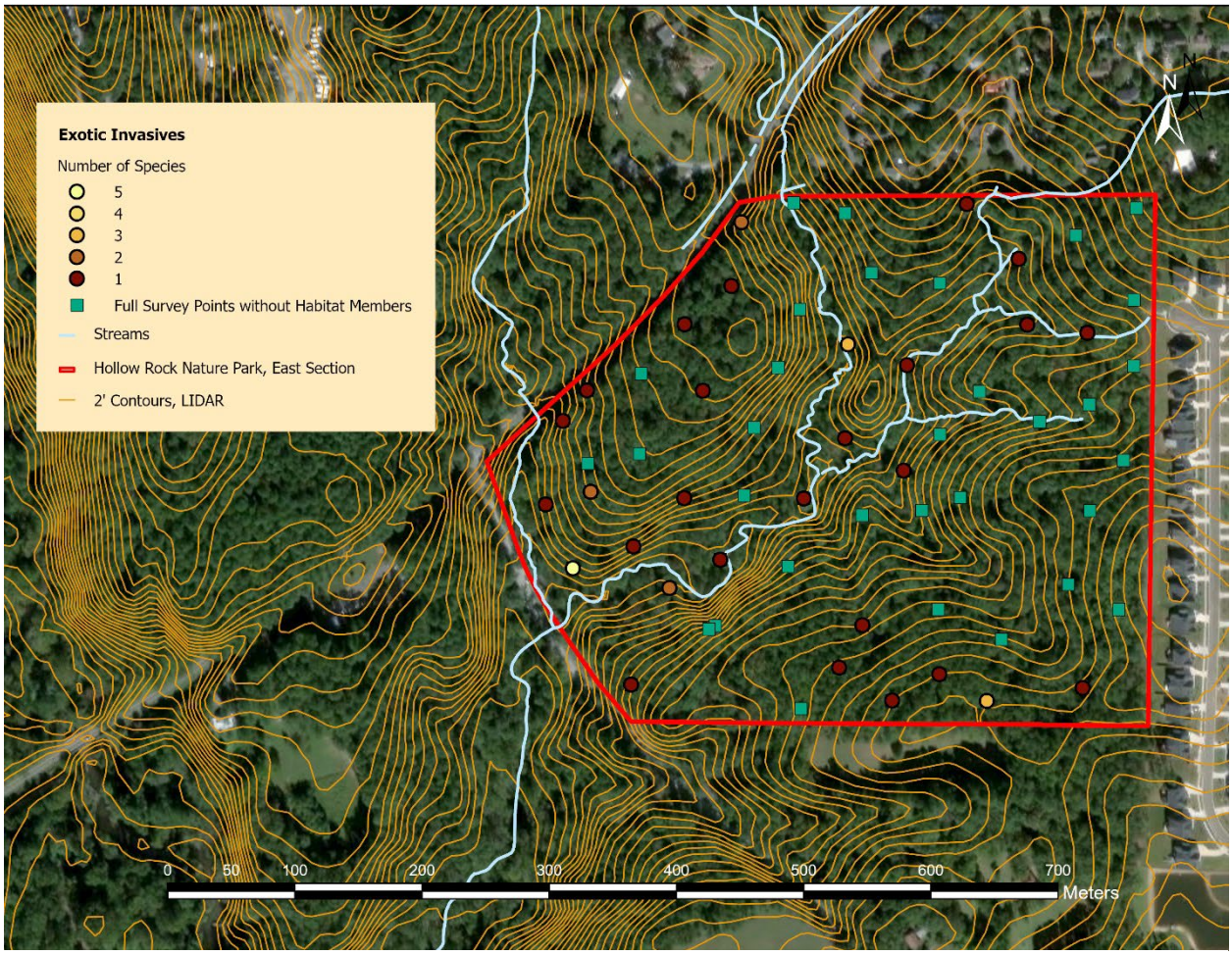


FIGURE 35

Discussion

The combination of habitats and species recorded in this survey is a good match to the features of Piedmont hardpan natural communities[6], consisting of more-or-less open woodlands growing on soils with a high clay content, especially montmorillonite (smectite). The deep layers of clay are difficult for plant roots to penetrate and the high shrink-swell properties of montmorillonite in particular further limit development of strong root systems, loosening when wet and strongly contracting when dry. These drought-prone soils further prevent the survival of seedlings that do manage to take root, and once the trees reach maturity windthrows are frequent, again due to poor root development and the loosening effect of the frequent shrinking and swelling of the soils. On top of all that, the dry, open character of the barrens and woodlands that develop on clay substrates are prone to wildfires, with their composition dependent on fairly frequent burning (for a detailed description of these communities, see the discussion of Piedmont And Mountain Glades And Barrens in Schafale (2023)).

Montmorillonite hardpan soils weather from both mafic and felsic rock formations and are very frequent in the Triassic Basins of the North Carolina Piedmont, where both sedimentary ridges and diabase intrusions are common. At the Hollow Rock study area both types are present, although most of the site is underlain by Whitestore Soils derived from the sandstones, siltstones, and mudstones that formed from sediments deposited in the ancient lakebed.

The natural community that appears to be the closest fit to the habitat factors and vegetation at the study site is the Mixed Moisture Hardpan Forest (Schafale, 2023). As in other hardpan-associated communities, this one occurs on montmorillonite clay substrates, generally derived from mafic formations but potentially from meta-sedimentary rocks. In terms of moisture, this community is intermediate between Upland Depression Swamp Forests and Xeric Hardpan Forests, with the term ‘xerohydric’ used to refer to “unusual mixtures of wet and dry soil conditions and of wetland and xerophytic plants (Schafale, 2023). Within these communities, these xerohydric conditions are relatively uniform across the community rather than segregated into separate dry and wet units. Although small, shallow pools are usually present during wet periods, they are dry during most of the year.

Vegetationally, the study area exhibits this sort of xerohydric condition, supporting a fairly uniform assemblage of wet and dry species growing in close proximity, for example, Post Oaks and American Ash occurring alongside American Hornbeams and Florida Maples. Although shallow pools were not observed during the summer when the survey was conducted, one small wetland was found where an old roadbed (noted in the archaeological report) crossed the flat top of the ridge located in the northeast corner of the tract. As shown in the photo below, just a pair of shallow ruts cutting into the topsoil was enough to reach a perched water table, allowing a thick growth of Netted Chain Ferns (*Lorinseria areolata*), rushes (*Juncus* sp.) and other wetland plants (see photo below).

[6] According to our definition, a natural community is composed of one or more habitats and a given habitat can belong to more than one natural community. The relationship is thus many-to-many. An individual natural community is closer to the definition of an ecosystem than are our habitats.

The species documented in sample plots include 34 (56%) of the species listed by Schafale as characteristic of this community type, with representatives included in each stratum. As described by Schafale, this community is distinguished by the co-occurrence of wetland and upland oak and hickory species. Although dominated by the dry-mesic White Oak (a common occurrence), both Willow Oaks and Post Oaks were present in significant numbers, and Northern Shagbark and Mockernut Hickories were found throughout the tract. Other juxtapositions of wetland and upland species were previously described in the habitat accounts, further supporting the xerohydric characterization of this community.

Several other aspects of the composition depart from Schafale's description, however, although he notes that degree of variation within this community is still poorly known. Three examples include the absence of Willow Oaks in the canopy and their occurrence mainly as transgressives and saplings; the high frequency of both Florida Maples and American Hornbeam over most of the study area; and the high frequency of Northern Shagbarks and the marginal presence of Southern Shagbarks. Even though not explicitly described, however, these features still reinforce the xerohydric nature of this community.

More puzzling is the high frequency of American Ash and other basophilic species. While this fits Schafale's Basic Variant of this community type, as was noted previously, this seems at odds with the supposedly acidic and nutrient poor character of Whitestore soils. The presence of such acidophilic species as *Vaccinium tenellum* and *pallidum* and *Hexastylis lewisii* further complicate the picture, suggesting that the montmorillonite clays present at this site may be derived from a mixture of mafic and felsic rock formations. As described earlier, outcrops of both sandstone and diabase occur within the study area, although they appear to be well segregated. Currently, there

is no good explanation for the mixed basophilic and acidophilic vegetation and a uniform mixture seems far less likely than the temporally mixed xerohydric moisture condition. Direct soil and/or geological analysis are required to sort out this situation.

Relationship Between the Habitat and Community Levels of Organization

Natural communities are described as including all of the species -- plant, animal, or otherwise -- that exist in a particular place, each type of which is distinguished by a unique composition of the species as well as a unique set of habitat factors. Habitats, on the other hand, are usually defined at the species level and refer to all of the factors, both biotic and abiotic, that determine the places – the habitats – where a particular species can reside more-or-less indefinitely as well as reproduce. Although unique to individual species, habitats can overlap to some degree between species, allowing multiple species to co-occur at particular places. The NCBP definition of multi-species habitats refers to places where such overlaps occur on frequent basis, with all species involved showing a high degree of fidelity to these sites. Like the habitats of individual species, these multi-species habitats are characterized by a particular set of habitat factors and by a unique combination of the species that share a high degree of fidelity to them, occurring as residents or breeding species only very rarely outside these places. However also like species' habitats, these multi-species habitats can themselves overlap to some extent and the resulting combination of intersecting habitats forms communities, possessing both consistent species composition and a unique combination of habitat factors.

The habitats present at a given community occurrence, however, typically represent just a subset of all the places occupied by that habitat, i.e., they are typically not defined by any one natural community. The communities, on the other hand, can theoretically be defined by a unique combination of habitats, governing both their composition of species and their combined set of habitat factors. In the case of the particular example of the Mixed Moisture Hardpan Forest present at the Hollow Rock study area, several habitats were described that possess species that are expected to occur at this site based on the presence of the habitat factors that characterize these groups. However, the factors used to describe a given habitat type are necessary for the presence of their species, but are not sufficient to predict the occurrence of particular species at a particular site: each species has a larger set of individual habitat factors that must be taken into account in addition to those that explain its fidelity to a particular habitat.

In the case of several of the habitats believed to occur within the Hollow Rock study area, large numbers of species were, in fact, not recorded. In view of habitats as just described, the necessary habitat factors for the entire group may be present but the species' individual factors precluded their occupancy. Given the description of the factors characteristic of Mixed Moisture Hardpan Forests, we strongly suspect that the strong swings in moisture – from xeric to wet or hydric – may account for these absences. Trees, for instance, that require the development of deep root systems or herbaceous species that require consistent moisture throughout the year are unlikely to thrive at this site. In this respect, the absence of these otherwise expected species can itself be used as a way to characterize the natural community present at this site, as is, in fact, routinely done in community descriptions.

On the other hand, identification of species that are capable of dealing with extreme conditions that exclude other species helps in the identification of previously undescribed habitats. If, for instance, some of the species that were found to have good quality occurrences within the study site but that cannot be placed in any of the established habitats that intersect at this site, then there is a strong likelihood that the extreme moisture regime and other factors related to the presence of montmorillonite clays may be uniquely necessary factors in explaining their presence at this site or any others like it. This would satisfy the conditions needed to identify a separate habitat type and is particularly true where more than one species shares these necessary conditions.

Three species may possibly meet these requirements. These include the Gray Dogwood (*Swida racemosa*) and Lewis's Heartleaf (*Hexastylis lewisii*), two rare to uncommon species mentioned by Schafale as associated with the Mixed Moisture Hardpan Forest community type. In neither of these two species, however, is there any evidence of strong fidelity to the set of habitat factors associated with this natural community. A third potential species is Blue Sedge (*Carex glaucodea*), which Weakley (2022) described as inhabiting "prairies, upland woodlands, especially in hardpan situations with alternating wet and dry conditions". Sedges with a wide-bladed morphology similar to Blue Sedge were, in fact, observed at several locations during the survey (see photo below) but lacked the inflorescences needed to determine their identity.

Conservation Recommendations

Whether or not it possesses species uniquely associated with it, the Mixed Moisture Hardpan Forest natural community already has a high priority for conservation; it is currently ranked as S2 at the state level and as G2 at the global level (NatureServe Explorer, 2024). Covering 45 acres, the occurrence at Hollow Rock is larger than all but one of the 23 currently extant examples identified by the Natural Heritage Program, the average size of which is only 18 acres. As a very mature occurrence and one that shows little evidence of disturbance, it probably merits

an A-level occurrence rank. The possibility that it represents a new variant boosts its priority for conservation even further.

Ideally, the entire extent of this occurrence would be brought into conservation protection. However, the potential for acquisition of additional land containing the habitat at this site is extremely limited due to the encroachment of dense development to the north and east of the existing preserve. There might be some opportunity, however, for acquisitions along the ridge that runs south of the preserve, which is still largely undeveloped. Some potential also exists for this habitat to occur within the portion of Duke Forest located immediately north of Erwin Road. This area is located just within the boundary of the Triassic Basin and includes an extension of the ridge located within the Hollow Rock preserve that supports this habitat. While Duke Forest lands are already protected, the existence of Mixed Moisture Hardpan Forest community type may not have been recognized and the site managed for other purposes.

While these areas may offer some opportunity for protection of additional units of the Mixed Moisture Hardpan Forest community in these areas, the best chance for restoration of this community type lies within the portion of the Hollow Rock Park located on the west side of Pickett Road. The same geologic formations appears to underlay this area as in the portion east of Pickett Road, but at some point in the last century, the natural forest was cut and replaced with a stand of Loblolly Pine, which still forms a major part of the canopy. Gradual removal of that species, opening up the canopy, would by itself help restore the natural features at that site, as would the direct planting of Shortleaf Pines, Post Oaks, and other species that are more natural to the unique natural community found within this preserve.

Within the study area, several of the species characteristic of the Mixed Moisture Hardpan Forest natural community appear to be declining as the result of loss of the periodic disturbance that once maintained it as an open woodland or barrens. Loss of wildfire is probably the most important factor and use of prescribed burning would normally be the appropriate remedy. However, the close encroachment of housing development may now preclude that option. Instead, selective cutting could be used to duplicate the effects of natural windthrows, which themselves are an important source of disturbance in this particular community type. Gaps in the canopy created through this process allow the regeneration of shade-intolerant species, including Shortleaf Pines and Blackjack Oaks, two characteristic species of this natural community that are in danger of being lost from this site. The heath thickets that are also characteristic of this natural community are also likely to benefit from more sunlight reaching the forest floor.

Four other species found within the preserve are in even more immediate danger of being lost. White Ash, Biltmore Ash, and Fringetree are all threatened with extirpation by impacts of the introduced Emerald Ash Borer. These species, however, are still present as seedlings and transgressives; if there are any effective controls that can be used to combat the beetle infestation, there is still a chance that these species can be restored as significant components of this ecosystem. Maintaining their genetic lines in a seed bank may also help if control of the beetle will take a significant amount of time.

The fourth species facing similar dire straits is Downy Arrowwood (*Viburnum rafinesqueanum*), which in this case is threatened due to over-browsing by White-tailed Deer. Although deer are

native species, they have proliferated mainly due to the loss of the predators that once kept their populations under control. Short of re-introducing wolves and pumas, hunting offers the best chance of bringing their populations back to a normal level. The winter closures of Duke Forest to allow bow hunters to cull the herd appears to be successful in this regard and should be considered as a model to be used at the Hollow Rock preserve.

Currently, the impact of exotic species of plants appears to be fairly low within the study area of this project, possibly related to the difficulties in dealing with the high swings in moisture characteristic of the Mixed Moisture Hardpan Forest community. The low level of impacts, however, may also be due to the lack of disturbances at this site. Exotic species may be likely to expand particularly due to the edge effects created by the clearing and development of the lands bordering the preserve on two sides as well as along the roads that additionally border or cut through the preserve. These species may also be able to expand as the result of restoring disturbances to the site. Close monitoring needs to done to detect any intrusion of these species and to enact control measures before they spread very far.

Need for Further Inventory

As we discovered in the NCBP inventory of the New Hope Bottomlands (Hall et al., 2022), the presence of a relatively intact plant community at a site cannot be taken as an indication of overall ecosystem integrity; the insect and breeding bird faunas were found to be in significant decline at that site despite the relatively extensive, high-quality vegetation that still exists there. A multi-taxa inventory, including groups involved at all trophic levels of the ecosystem, including herbivores, predators, and detritivores, was needed to assess the true integrity of the site, due to important differences in how they have been affected by urbanization and other changes in land use. While some information was gathered during that survey at Hollow Rock, we strongly recommend that the moth and breeding bird populations – two of the groups most strongly declining in the New Hope Bottomlands – be more thoroughly inventoried. Soil invertebrates and fungi are among the groups most likely to be affected by the unusual substrate conditions present in the study area and should also be given more attention.

Although plants were selected as being especially suitable for mapping the habitats present within the study area – as confirmed by this survey – the methodology used both for mapping and assessing habitat quality can be accomplished the same way for any taxonomic group. Where species have been identified as belonging to one of our multi-species/multi-taxa habitats, the presence of a residential population of any of them demonstrates the presence of their particular habitat and can be used to map its distribution and extent within the study areas. The use of viability ranks and PS scores can likewise be applied to any species, making all taxa useful for assessing the quality of a given habitat occurrence or, conversely, to estimate the degree of risk to that occurrence and hence its priority for conservation action. In the midst of the sixth great extinction event experienced by this planet, all biotic surveys need to assess the integrity not only of individual species of high conservation concern, but also the ecological components of biodiversity. The methods we are developing are aimed at both.

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