A Survey of the Big Shellbark Hickory, White-nymph, and Other Species Associated with Rich Alluvial Forest Habitats in the New Hope Floodplain of Durham County

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North Carolina Biodiversity Project

For
The Durham Open Space Program

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Big Shellbark Hickory

Reflexed Wild Ginger

Smooth Yellow Violet

American Trout-lily

Origin and Purpose of the New Hope Mapping Project

The survey described here is a follow-up to a much larger biodiversity inventory conducted by the North Carolina Biodiversity Project (NCBP) in the Durham County portion of the New Hope Creek floodplain in 2021 and 2022 (Hall et al., 2022). Whereas that survey involved a very broad-brush effort to document as much of the taxonomic diversity of the floodplain as possible, the current study focuses much more narrowly on mapping the distributions within the New Hope floodplain of two of its rarest species, Big Shellbark Hickory (*Carya laciniosa*), and the White-nymph (*Trepocarpus aethusae*), both of which appear to have their best (or only, in the case of the White-nymph) populations in the state along New Hope Creek.

Additionally, we mapped areas that support species that appear to be associated with rich, alluvial soil habitats, a key feature of this natural area: in addition to the Big Shellbark (and potentially, the White-nymph), 75 species were documented in the 2021-22 inventory that we believe to belong to these habitats. This information can be used to guide stewardship efforts aimed at the Big Shellbark, which appears to have been lost from several such areas in the floodplain. Equally important, it serves the stewardship needs of the habitat itself – a significant conservation target in its own right.

As in the 2021-22 Biodiversity Survey, the current project was commissioned by the Durham Open Space Program and was conducted under the auspices of the NCBP by biologists belonging to that group[1].

Project Description and Methodology

The study area of this project includes tracts of county-owned lands extending from just south of the Trinity School at the north end of the project area to Old Chapel Hill Road at the south. Although Hollow Rock Nature Park was included in the previous survey, this project focused solely on the tracts owned by Durham County along the floodplain of New Hope Creek as it flows through the Durham Triassic Basin. All of the Durham-owned parcels were visited during this survey, but Parcels 8142966, 138572 and 138511 were largely flooded, with surveys possible only in some of the drier portions of those tracts.

Transect surveys were conducted on seven trips made between May 25 and August 17, 2023. These trips focused on mapping the occurrences of the two target species, Big Shellbark Hickory and White-nymph, along with two other herbaceous species -- Reflexed Wild-ginger (*Asarum reflexum*), and Smooth Yellow Violet (*Viola eriocarpa*) -- that appear to be confined to areas supporting the highest concentrations of species associated with rich alluvial soil habitats. These two species were selected in particular since they remain above ground through the summer, when the surveys were conducted.

Waypoints were recorded using a Garmin Montana 700 Series GPS unit, with notes taken on the species and other features observed at a particular location using a Sony Digital Voice Recorder.

[1] We would like to thank David Bradley, who accompanied us on one survey visit and who addionally provided key locational data for the White-nymph. We also thank Pat Coin, who joined us for a particularlly wet slog through the bottomlands.

Observations were recorded whenever a new patch of the species listed above was either entered or departed. Within a patch, a zig-zag path was followed, with individuals of the species usually recorded at approximately 50’ intervals, with sufficient numbers of observations to indicate the extent of the patch. For the tree species, basal diameter at breast height was estimated visually and notes were made on the number of individuals present in the immediate vicinity of the observation point.

The presence of other species was also noted, particularly Painted Buckeye (*Aesculus sylvatica*), which was probably another species that should have been incorporated as a mapping target. Additional waypoints were used to record the location of habitat edges, pools, and the location of additional species of plants or animals. Data from the GPS unit were downloaded and stored as shapefiles using the DNRGPS program created by the Minnesota Department of Natural Resources. Maps and GIS analysis was done using ESRI’s ArcMap program. A map showing the location of the survey tracks and waypoints is presented in Figure 1. The tracks we followed were recorded continuously by the GPS unit, but with an apparent lower degree of accuracy than the waypoints.

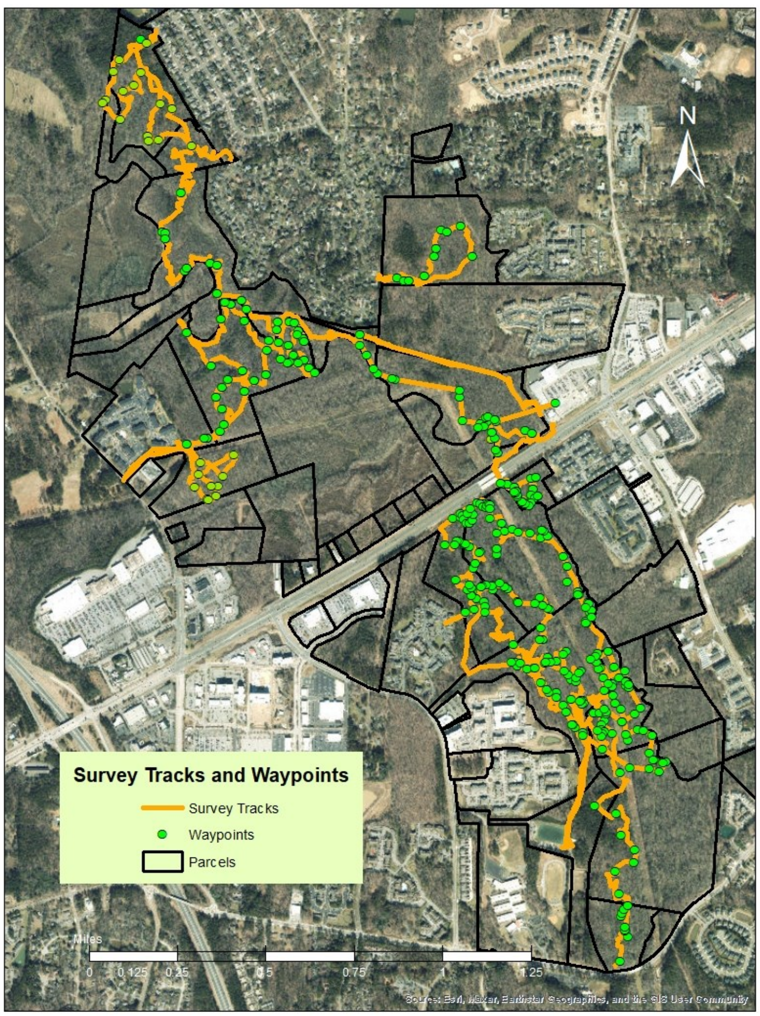


FIGURE 1. SURVEY TRACKS AND WAYPOINTS

Big Shellbark Hickory

Big Shellbark Hickory (*Carya laciniosa*), along with the White-nymph, is state-ranked as S1, the highest possible value, by the North Carolina Natural Heritage Program. In plain words, that rank means that it is considered to be Critically Imperiled within the state, having a very restricted range, a small number of individuals, and a limited area of occupancy, all of which contribute to making it highly vulnerable to extirpation from the state.

This very large bottomland tree – reaching up to 134 feet tall – is primarily associated with the limestone-rich areas of the Ohio Valley and upper Midwest, where it grows in bottomlands with exceptionally rich alluvial soils (Schlesinger,1990; Chafin, 2020; LeGrand et al., 2023). East of the Appalachians, it is extremely rare over most of the region (see range map provided by Schlesinger), and is listed as either Imperiled or Critically Imperiled from Maryland southward (NatureServe Explorer, accessed 2023-10-08). In North Carolina, there are just a few viable occurrences: a cluster of small populations located in the lower floodplain of the Roanoke River and the one located along New Hope Creek. Of these, only the New Hope population is given an Occurrence Rank of A, meaning Excellent Estimated Viability. How this species reached these areas from the Upper Midwest is puzzling, although the occurrences along the Roanoke may have originated in the limestone-rich Ridge and Valley Province of Virginia, where this river has its headwaters (see LeGrand and Hall, 2014). No such route to the limestone areas of the Midwest exists for the New Hope population, however, but its presence there indicates that it is not dependent on limestone per se, but can grow in other types of nutrient-rich, relatively high pH alluvial soils.

The New Hope Creek population was first discovered in 1998 in a NHP survey of the Jordan Lake Project Lands by Harry LeGrand (LeGrand, 1999). Until the NCBP survey was conducted in 2021-22, the known limits of this population closely corresponded to the US Army Corps lands in the southern part of the study area, with some also known to occur in the privately-owned tracts immediately north of the USACE property. The NCBP survey conducted in 2022-23 extended these limits north of US 15-501, but with only a small number of individuals, mostly young, found in that area.

The current survey was conducted primarily on the Durham County tracts, with one visit also including USACE lands on the southwest portion of the floodplain. The results of the survey are shown in Figure 2 (including some of the points recorded in the previous survey). Except for one Durham tract located on the east side of New Hope Creek just south of the US 15-501 bridge, tracts on the east side of the creek south of the highway were not included in the survey. North of the highway, extensive tracts owned by Durham County are located on both sides of the creek, all of which were visited during the course of this project (see Figure 1).

All hickories with large leaflets encountered during the survey transects were closely inspected. Those that had seven to nine leaflets and possessed a “claw” of leaf rachises persisting from the previous year were identified as Big Shellbarks. Northern Shagbarks (*Carya* ovata) were also common in the floodplain and any tree with only five leaflets was treated as such even though many of them possessed at least a few persistent leaf rachises. In some cases, the size of the nuts found under the trees or the shagginess of the bark were used as supplemental information..

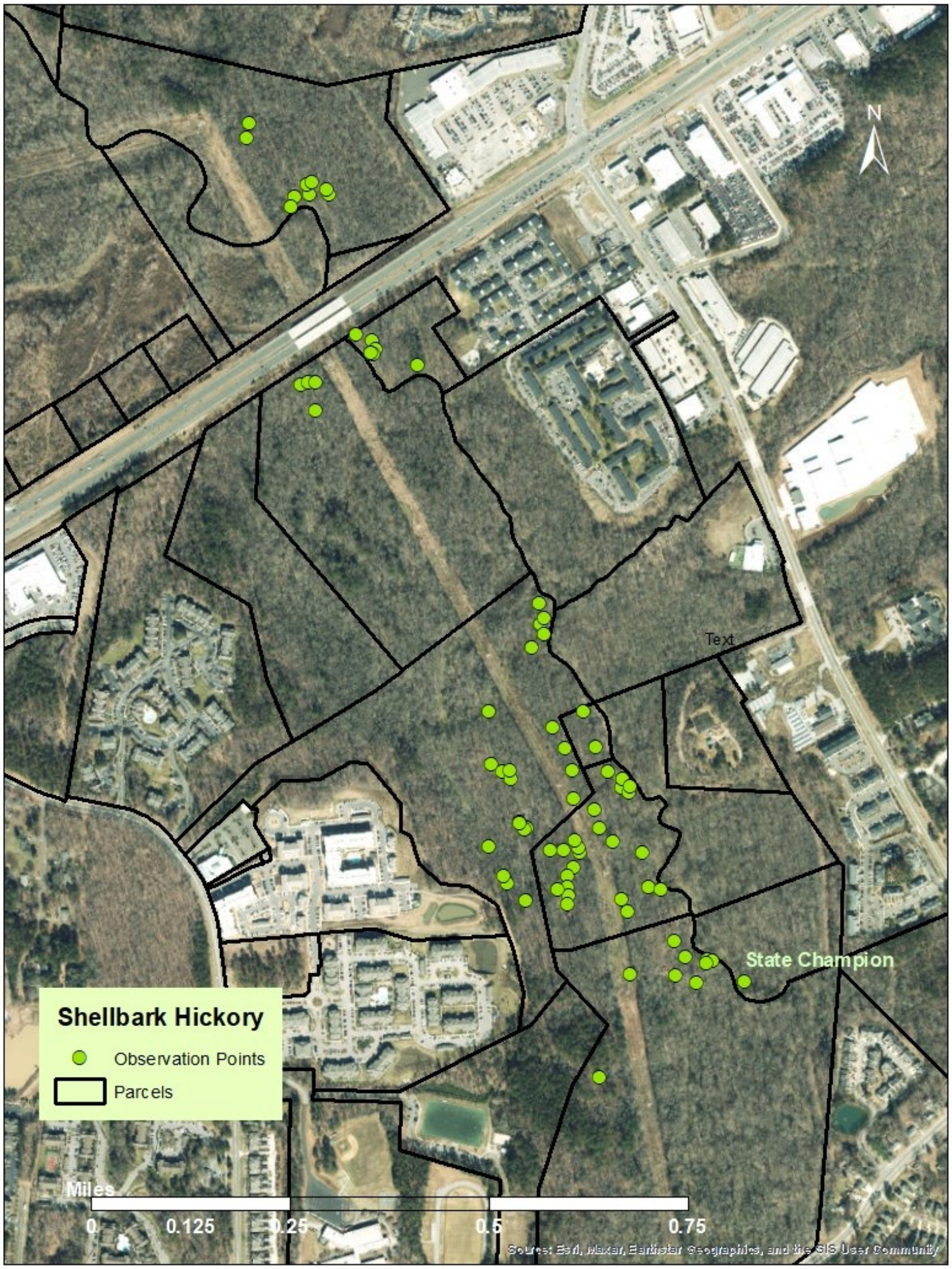


Figure 2. Big Shellbark Hickory Observation Points

As shown in Figure 3, virtually all of the trees identified as Big Shellbarks were growing on the flat areas of the floodplain, usually close to the main creek channel or along channels that are flooded during high water events. Northern Shagbarks (mapped more sporadically) were also common in these areas but were also found growing on low, seldom flooded ridges (based on thick leaf litter accumulation) or on the adjoining slopes. Mockernuts (not mapped), which also have seven or more fairly large leaflets, were encountered exclusively up on the slopes. Bitternuts (also not mapped), on the other hand, were mainly observed in the floodplain but usually have more than seven leaflets and ones that are much smaller in size than those of the Big Shellbark.

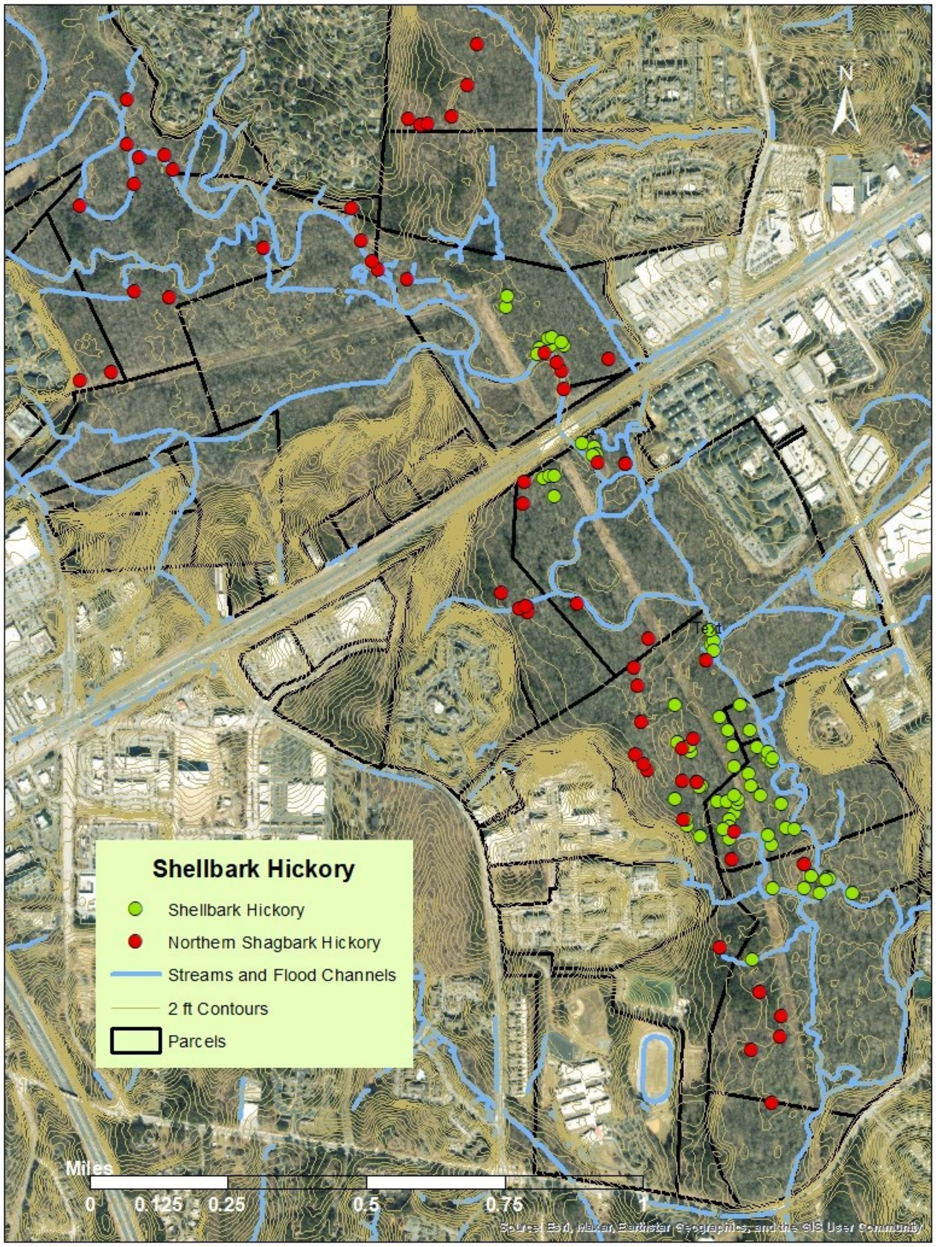


FIGURE 3. COMPARISON OF SHELLBARK AND SHAGBARK DISTRIBUTIONS

Figure 3 shows that Big Shellbark Hickories occupy a much smaller range within the New Hope floodplain than does the Northern Shagbark, despite the fact that the Big Shellbark is the more specialized as a floodplain species. The Aggregate Points function in ArcMap can be used to calculate the area of a concave polygon that groups all the observation points falling within a certain separation distance from one another. As shown in Figure 4, a 300 m separation

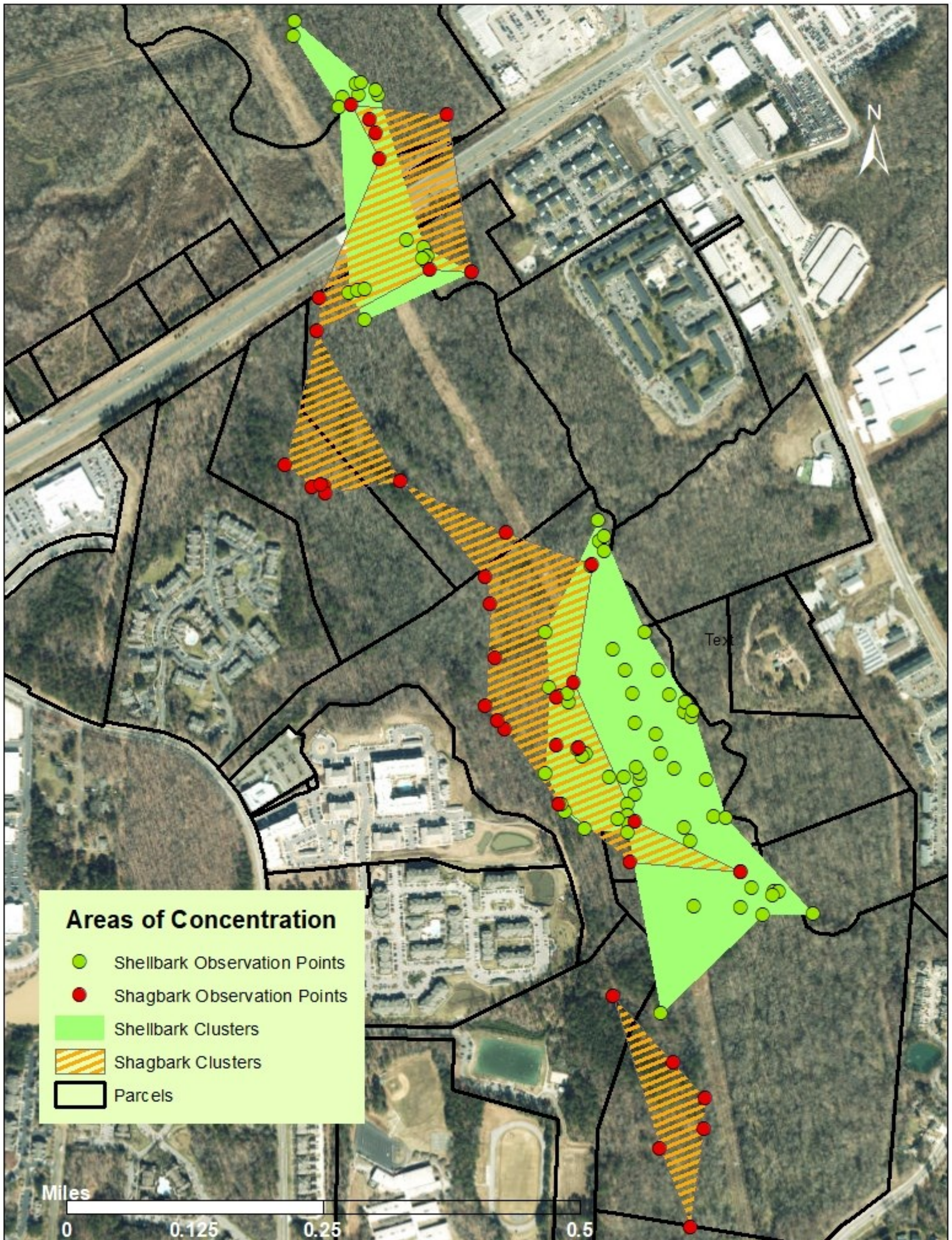


FIGURE 4. CONCENTRATIONS OF SHELLBARK AND SHAGBARK HICKORIES

distance results in the observation points for the Big Shellbarks falling within two such polygons, one in the southern part of the study area and one that includes the observations on both sides of US 15-501. Summing the area of these two shapes, the Big Shellbark, as currently mapped, occupies only 16.84 ha (41.61 acres). This compares to 25.09 ha (61.99 acres) for the Shagbark clusters shown in the same frame, which were not surveyed nearly as thoroughly.

One possible explanation for the greater restriction of the Big Shellbark is its need for particularly rich soils. Although both species of hickories are associated with nutrient rich, moist soils, the Big Shellbark is associated with a narrow band of rich soils that extend along the floodplain of New Hope Creek but apparently not Mud Creek. Northern Shagbarks, however, grow along the floodplains of both creeks, indicating the generally wider range of soils they occupy. Across their very wide range in eastern North America, Shagbark Hickories occur across a broad range of soil types, although with a greater preference for richer soils particularly in the southern part of their range (see discussion for *Carya ovata* by Graney, 1990). Further discussion of the association between Big Shellbarks and the richest soils in the study area will be presented in the section on Habitat Mapping below.

The presence of the state champion Big Shellbark within the New Hope floodplain (see Figure 2) indicates that this species has been present within the area for a very long time. According to the NCFS Database of Champion Trees (NCFS, 2023-09), this specimen possesses a dbh of 36.61”, a height of 123’ and a spread of 78’. Based on an annual increase in diameter of 0.08” per year for saplings and 0.12” once pole timber size (4-10”) is reached (Schlesinger, 1990), the age of this tree may be estimated as follows:

$4/0.08 + (36.61-4) / 0.12 = 50 + 272 = 322$ years.

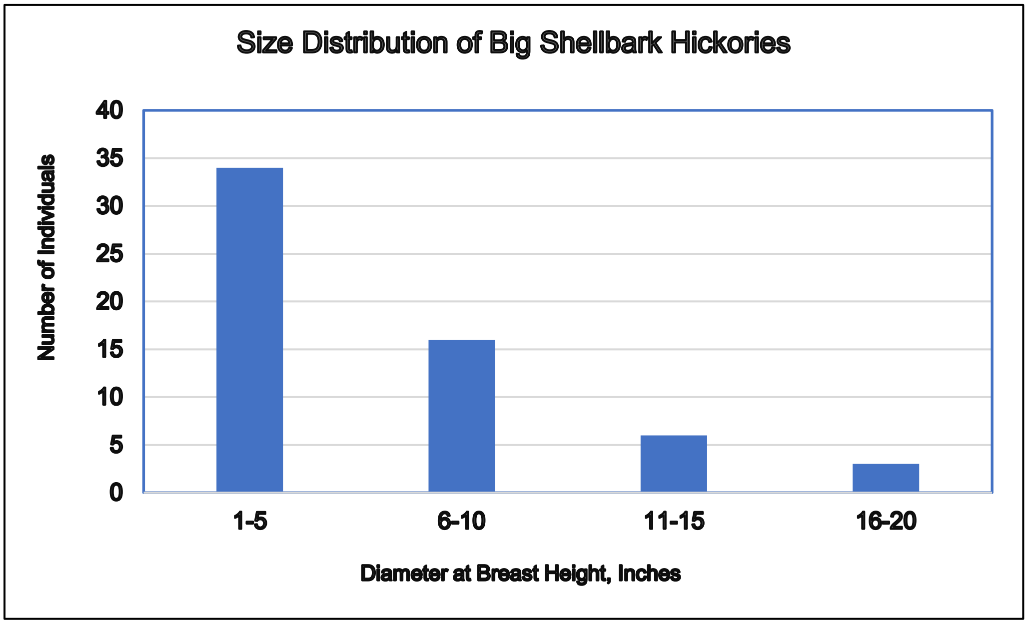
That would place the species along New Hope Creek as far back as the early 1700s, preceding the first European colonists who began settling in this area around 1750. Although several individuals of other species of that size were found, with some reaching over 4’ in dbh, the largest Big Shellbarks encountered during the survey were two that were about 20” dbh, making them much younger than the champion tree but still about 180 years old, dating back to the 1840s. All of these large trees may have been left as shade trees in the pastures that may have been carved out of the forest by the European settlers. We found strands of old barbed wire embedded in trees at several locations and old relict Red Cedars (and their logs) can be found well out in the floodplain, indicating that much more open environmental conditions existed in the past.

By 1940, much of the southern part of the study area had regained its forest, with an almost complete canopy of hardwoods visible in an aerial photo taken at that time[2] – a portion of which is shown in Figure 5 with the current records for Big Shellbarks superimposed.

[2] Obtained from the University of North Carolina Library collection of USDA Historical Aerial Photographs

FIGURE 5. 1940 AERIAL PHOTO OF THE STUDY AREA SHOWING CURRENT LOCATION OF SHELLBARKS

Individual trees that existed in 1940 may have already have been 50 years old at that time, and with another 80 years of growth, we would expect to see at least a fair number of Big Shellbarks as old as 130 years, with diameters of about 20”. Instead, found only two such individuals were found (in addition to the state champion), with the majority we observed being much smaller, as shown in the histogram below.



No changes in the extent of the forest cover are evident the southern part of the study area, as shown in aerial photos taken in 1955 and 1972, suggesting that if there were at least a few Big Shellbarks present in 1940, that it has taken all this time to repopulate the area to the extent that we now observe. Chafin (2020) notes, in fact, that this species is very slow to recover from timbering, due to slow growth and late maturation, with seeds not produced until the trees reach approximately 40 years (Schlesinger, 1990), or at least 4” in diameter. In comparison, Northern Shagbarks, which have a similarly slow growth rate and that again reach maturity at around 40 years (Graney, 1990), have managed to spread over a much greater area of the floodplain and the surrounding slopes. However, we again found only four individuals that were 20” in diameter. Their more rapid spread, therefore, may have been facilitated due to their greater tolerance for moisture-regimes and soil types, but may also be explained by their smaller nuts, which may be more easily dispersed by Eastern Gray Squirrels than the much larger and heavier nuts of the Big Shellbarks.

On the positive side, the large number of small Big Shellbarks we found is an indication of successful reproduction and ongoing recovery by this species. Within the southern cluster shown in Figure 4, the density of Big Shellbarks appears to be fairly high, although we did not conduct any quantitative sampling that would give precise estimates. Based mainly on the concentration of the species within this cluster – the only one known prior to the 2021-22 survey -- the Natural Heritage Program assigned this population an A-level Occurrence Rank, i.e., having Excellent Estimated Viability (rated in 2017, BIOTICS database).

While we agree with this estimate regarding the quality of this occurrence, the population of Shellbarks in the New Hope floodplain is still very small, with the combined extent of both clusters only 16.84 ha (41.61 acres). Although additional individuals are likely to be found on the adjoining private lands or on un-surveyed portions of the Corps Lands to the south, the total area covered by the population is likely to remain fairly constricted, limited by both topography and the apparent dependence of this species on the richest soils in the floodplain. Based on both the limited spatial extent, relatively small number of individuals – most of which are young – and the lack of any population outside of this floodplain that could provide a source of recolonization following a major extirpation event, we rate the probability of extirpation somewhat higher than the A-level Occurrence Rank would indicate. Over the next twenty years, a prolonged heat wave, drought, or major fire all seem possibilities, given the effects of climate change, and the probability of extirpation could be as high as 30 or 40%. Based on those rates, we estimate the occurrence would correspond to either a Good Estimated Viability (B-level Occurrence Rank) or a Fair Estimated Viability (C-level Occurrence Rank).

White-nymph

The only other species found in the Durham County portion of the New Hope floodplain that is currently ranked as S1 is the White-nymph (*Trepocarpus aethusae*), a small annual forb first found in North Carolina in 2021 (White and Pyne, 2021). The main range of this species is the Gulf Coast, from Galveston Bay in Texas to the Apalachicola River in the Florida Panhandle, with populations also ranging up the Mississippi Valley to southern Illinois and Kentucky (GBIF, 2023). It appears to be much rarer along the Atlantic Slope, with a disjunct population recorded at the Savannah River Ecology Laboratory (SREL*)* on the South Carolina-Georgia state line (Knox and Sharitz, 1990), and the population in the New Hope Creek located 240 miles northeast of that site (see range map in GBIF, 2023). This species is considered somewhat rare throughout its range (Wilm and Taft, 1998) and is listed as Special Concern in Kentucky. If native, the population found along New Hope Creek would certainly warrant giving it Endangered Status within North Carolina.

Knox and Sharitz (1990) described this species at SREL as usually associated with calcareous soils and Weakley (2022) also described it as “associated with rich moist forests, calcareous glades.” As with the Shellbark Hickory, the presence of this species in the New Hope Floodplain may be at least partially explained by the rich alluvial soils found at this site. This species, however, also appears to be somewhat weedy. Wilm and Taft (1998) described the White-nymph as adapted to periodic disturbances in floodplain habitats and “dependent on flooding dynamics for dispersal to open habitats where they can sort into sites free, at least temporarily, from intense competition.” They also noted that it is tolerant of a variety of moisture and insolation conditions, ranging from wet forests to fairly dry fields. While tolerant of both deep shade and complete sun, it appears to prefer partially shaded openings in the forest. Nelson (1993, cited by Weakley, 2022) states that despite "something of a reputation as a rarity", *Trepocarpus* is "a reasonably successful weed."

The locations where White-nymphs have been recorded, both in the current survey and previously by White and Pyne (2021) and David Bradley (Durham Open Space Program), are shown in Figure 6.

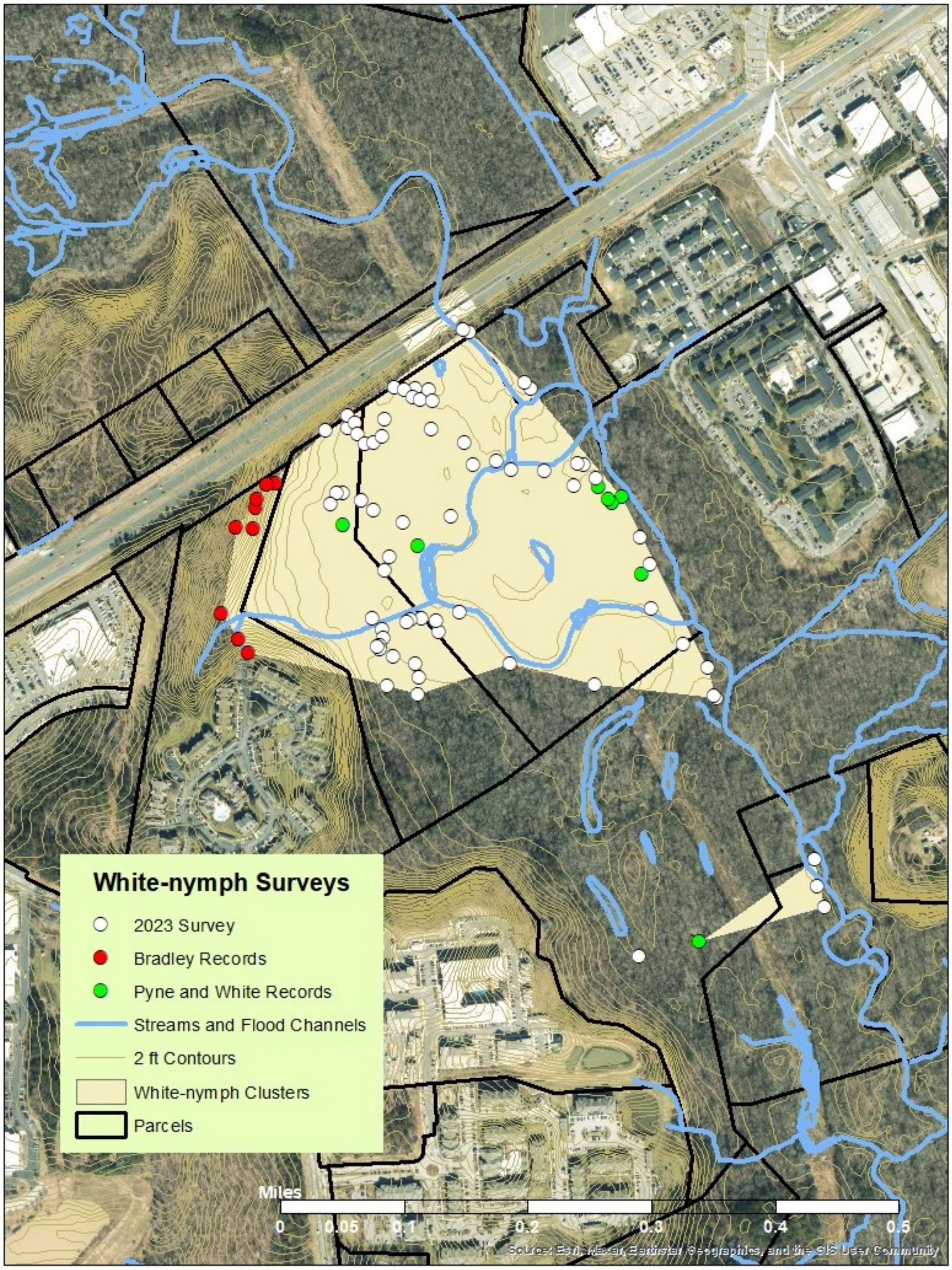


FIGURE 6. WHITE-NYMPH OBSERVATION POINTS AND CLUSTERS

Using the same Aggregate Points function described above for the Shellbark Hickory, again using a 300-meter separation distance, there appear to be two clusters of this species. The larger, located at the north end of the New Hope Bottomlands, occupies just 18.90 ha (46.70 acres) and the combined extent of both clusters is only 19.43 ha (48.01 acres). Although not uncommon in these areas, particularly the northern cluster, this species occurs primarily as a number of small scattered patches rather than forming a continuous expanse.

Figure 7 shows the spatial relationship between White Nymphs and the combined observation points of Big Shellbark Hickory, Reflexed Wild Ginger, and Smooth Yellow Violet.

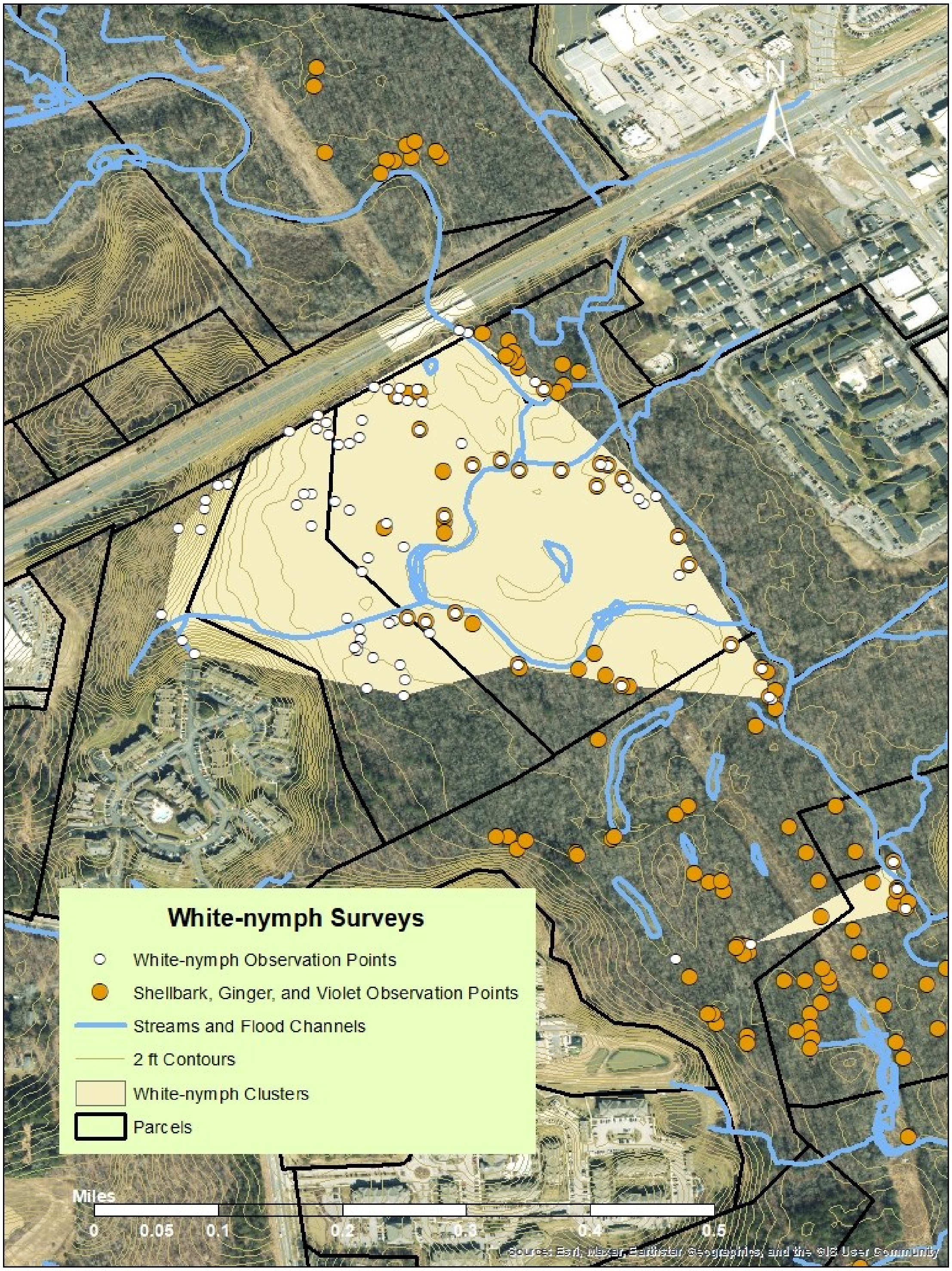


FIGURE 7. COMPARISON OF THE OBSERVATION POINTS OF WHITE-NYMPH AND RICH ALLUVIAL SPECIES

In the eastern half of the larger, northern cluster, the majority of the White-nymph observations were located along the creek or flood channels and closely coincide with the points for the species we believe prefer rich alluvial soils. There are also a large number of observations for this species in the western half of this cluster, however, where none of the rich alluvial species have been observed. In fact, some of the largest patches that we observed were growing in the semi-open areas of the floodplain where a grove of Green Ash had been killed by the Emerald Ash Borer. This pattern is similar to what Wilm and Taft observed: that the species prefers moderately open areas in floodplains and may even have a preference for rich soils, but they are not limited to such areas and can take advantage of somewhat disturbed sites.

As a "reasonably successful weed," White-nymphs would be pre-adapted to be at least somewhat invasive: if transported into new areas, its tolerances for a range of floodplain habitats and high reproductive rates associated with being an annual herb, could allow for a fairly rapid colonization of an area, just as has been the case for many of the more exotic species that are now widespread in the New Hope floodplain.

Wilm and Taft noted that the seed of White-nymphs can float for weeks, and speculated that water-borne dispersal was the most likely mode used by this species. In that case, the patch discovered by David Bradley – located at the highest elevation recorded for this species in the project area – could be the point of origin. This point is located in a mowed area next to an apartment complex, where soils or plantings used for landscaping could have been a source of seeds originating somewhere further south where the species is truly native.

From that point, a small intermittent stream that has its headwaters close to where Bradley found the patch at the apartment complex could have provided the avenue for colonization in the floodplain directly downhill from the apartments. However, White-nymphs are also present in the floodplain upstream from those patches, which indicates a second avenue for colonization. In fact, Bradley discovered several more patches growing on a sewer line easement that runs obliquely downhill along the slope to the northeast, intercepting an open, somewhat marshy highway right-of-way where a number of patches of the plant were recorded during our 2023 survey. That right-of-way itself runs downhill to New Hope Creek, where several patches of White-nymph were found, opening the way to colonization of the entire floodplain downstream of that point via flooding events. No colonization would have been possible to the upstream areas to the north, however, and, in fact, we found no White-nymphs north of the highway, unlike the Shellbark Hickories and Reflexed Wild Ginger whose habitat preferences are overlapped by those of the White-nymph.

A map summarizing these hypothesized routes of invasion is shown in Figure 8. The yellow arrows indicate the direction of downslope/downstream flow.

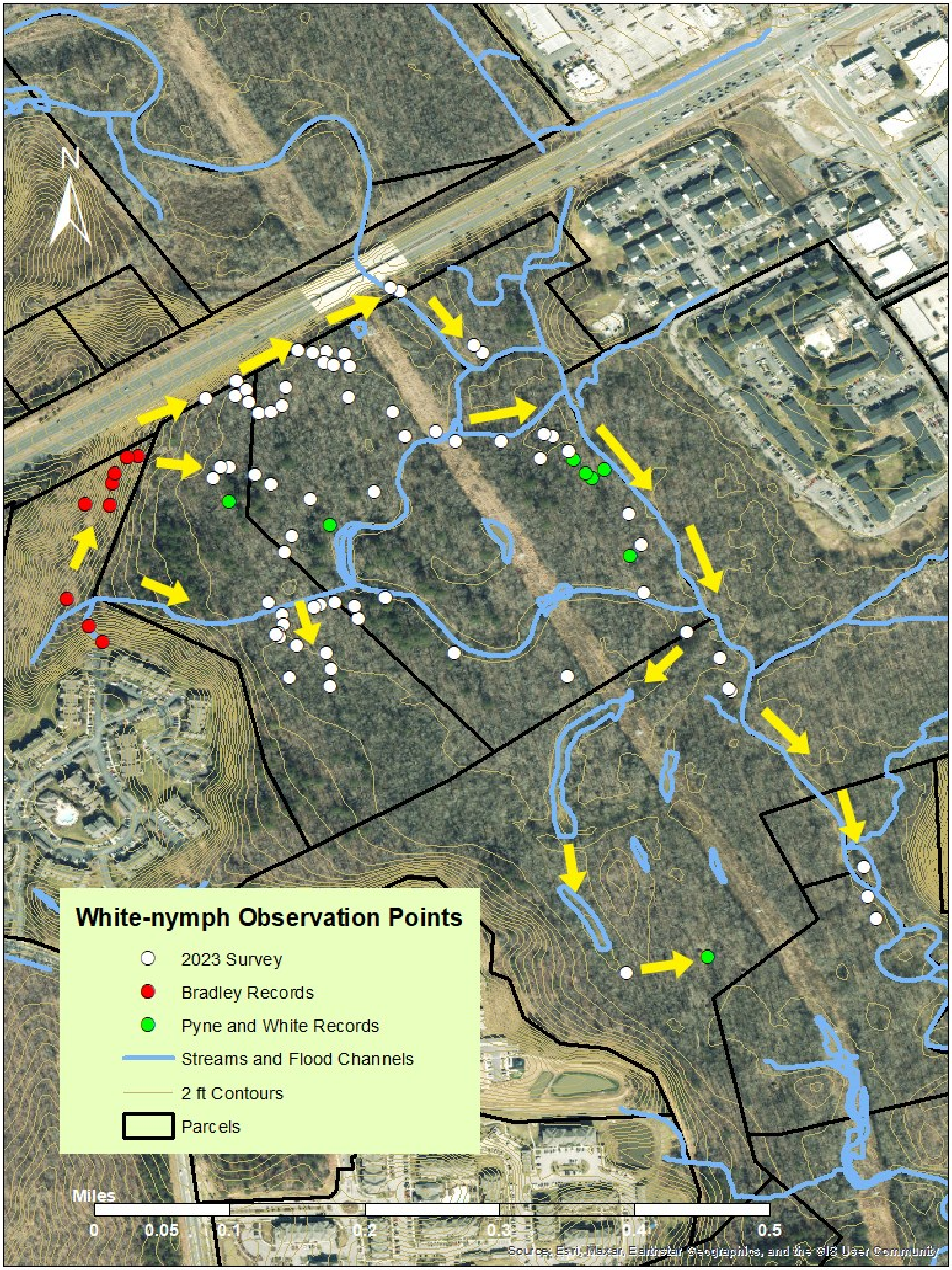


FIGURE 8. POSSIBLE ROUTES OF SPREAD OF WHITE-NYMPH

Although the evidence for this hypothesis is entirely circumstantial, it strongly suggests that this species is a recent invader of this area, becoming established possibly in the late 1990s, when the apartment complex was developed, or in 2007, when the sewer line right-of-way appears to have been cleared (based on an aerial photo for that year shown in Google Earth). If correct, this species should be regarded as an exotic invasive rather than as a very rare relict like the Shellbark Hickory. Instead of the state rank of S1 it currently holds (BIOTICS, accessed 2023-09-27), we recommend that it be re-ranked as SE, State Exotic, and not viewed as a target for conservation efforts. Our main recommendation with regard to this species is to continue to monitor its status and distribution. If it is a colonizer, we expect to see it become increasingly common in areas downstream from where it has been currently documented it. If this is the case, it should be treated the same way as any of the many other exotic, invasive species that have been documented in the New Hope floodplain.

Other Rare Species

Figure 9 shows the location of 38 species that were identified in the 2021-22 survey as rare or noteworthy within the New Hope Floodplain. Only one of these species, the Yellow-crowned Night Heron, is considered rare by the North Carolina Natural Heritage Program, who rank it as S2 ("Imperiled"). The rest are included either on the NHP Watch List or – the majority – belong to groups that have yet to be assigned ranks by the Natural Heritage Program. These include Slime Molds, Fungi, Lichens, Mosses, Spiders, and Micro-moths. Maps for each of these taxa – not included in the previous NCBP survey – are provided in Appendix A of this report.

The habitat associations for most of these species have yet to be described. However, two of these species are included in habitats covered in the current project and their observation points are plotted in Figure 10.

American Trout-lily (*Erythronium americanum*) is a member of the Rich Wet-Mesic Hardwood Forests habitat and was actually recorded at several locations within the New Hope Bottomlands south of US 15-501. Additionally, one record was provided by Julie Tuttle for a site located north of 15-501, in an area close to where we documented the presence of Big Shellbark Hickories and Reflexed Wild Ginger.

Kentucky Warbler (*Geothlypis formosa*) is also a member of the Rich Wet-Mesic Hardwood Forests habitat (see description in LeGrand, H.E.; Haire, J.; Swick, N.; and Howard, T. 2023). This species was a target of the 2021-22 survey but was not detected. However, one singing male was observed in the current survey in an area well-upstream from where the most intensive bird surveys were conducted. Also worth mentioning, although belonging to a habitat not covered in this report, is an observation of a Hooded Warbler (*Setophaga citrina*). This is another species that was not observed at all not in the 2021-22 survey. This year, however, both of these species were observed during the nesting season and well after migration was over.

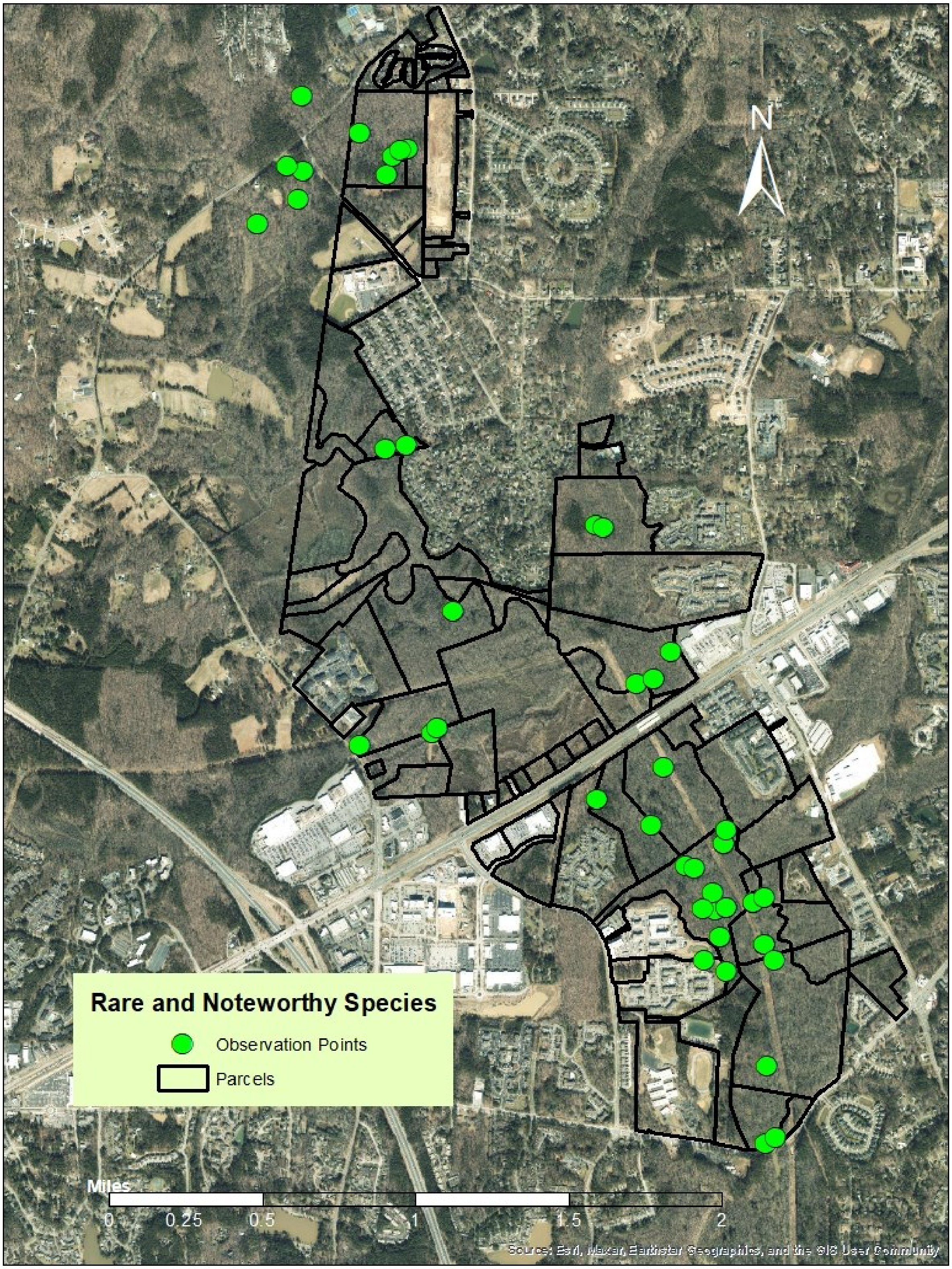


FIGURE 9. LOCATIONS OF RARE AND NOTEWORTHY SPECIES DOCUMENTED IN THE PROJECT AREA

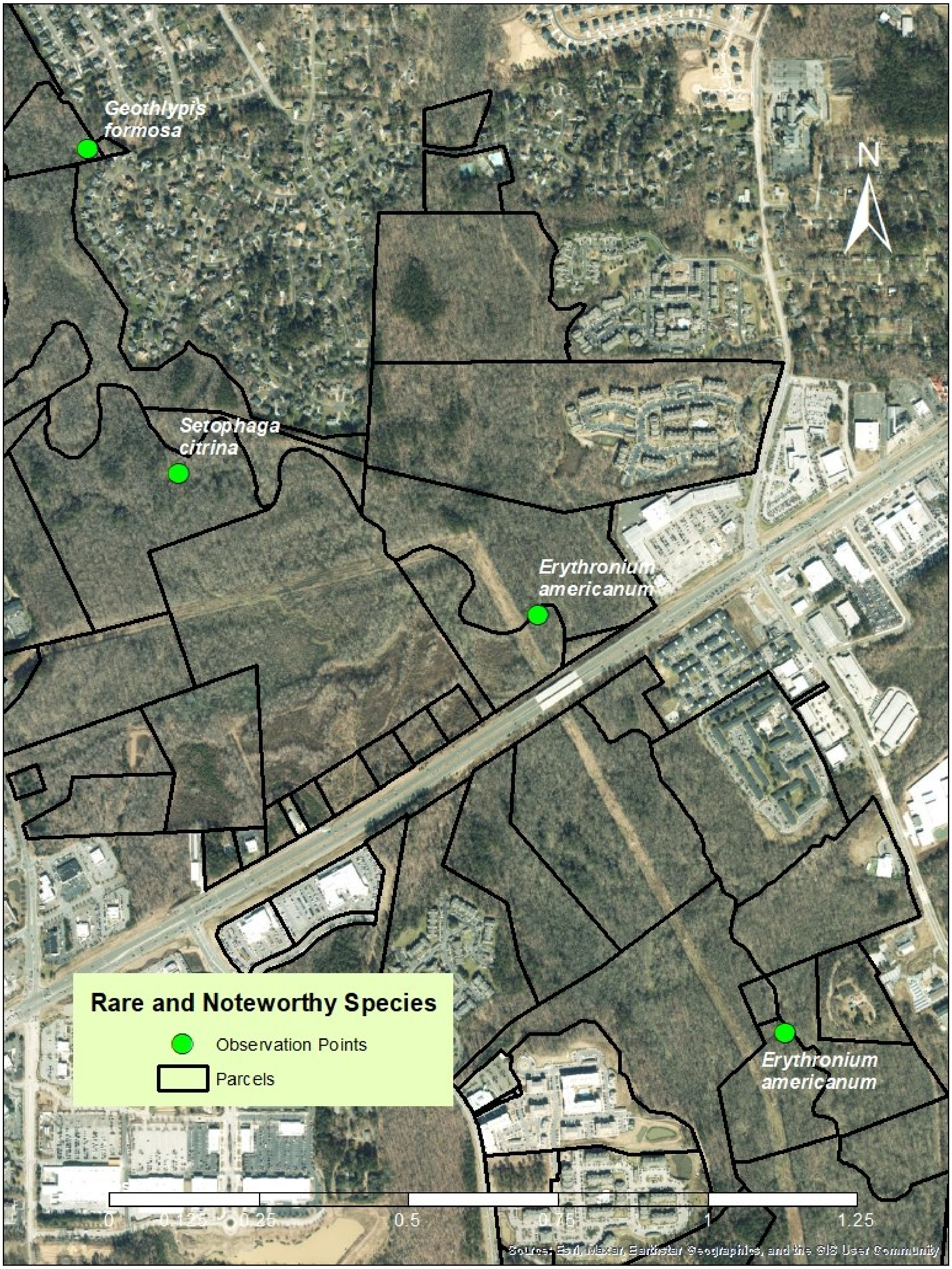


FIGURE 10. SELECTED RARE SPECIES OBSERVATION POINTS

Rich Alluvial Hardwood Forests

In addition to mapping the occurrences of the individual species described above, a major goal of this project was to map the habitats of these species, as well as those of other species whose habitats strongly overlap with those of the main targets. Given the strong association between the Big Shellbark Hickory and deep, rich alluvial soils, our focus in this regard is on the range of species and their habitats that share those factors as defining features or key requirements. In the multi-species approach that NCBP uses to define habitats (in the Habitats of NC Website, currently under development), there are three of our MSCD[3] Habitats that have these features:

Rich Wet Hardwood Forests, whose species are confined to forested floodplains that have alluvial soils with a relatively high pH and a high content of nutrient minerals. Shellbark Hickories, Sycamores, Box Elders are all members, as are several of their obligate herbivores, including the Sycamore Tussock Moth, Maple Zale, and the Box Elder Bug.

Rich Wet-mesic Hardwood Forests, whose species make use of forests growing on rich mesic slopes in addition to rich floodplains. Species associated with these habitats include trees such as Northern Shagbark Hickories and Florida Maples; shrubs such as Common Pawpaw, Painted Buckeye, and Spicebush; herbs such as Reflexed Wild Ginger, Smooth Yellow Violet, American Trout-lily, and Spreading Chervil. Again, there are a number of animals that are specialized herbivores of these plants, including Zebra Swallowtail, Asimina Webworm Moth, and Buckeye Petiole Borer Moth, all of which are equally good members of this habitat as their host species.

Rich Wet-dry Hardwood Forests, whose species span a wide range of moisture regimes but that again require forests growing on nutrient rich soils. Species associated with this habitat include plants such as Common Hackberry, Wafer-ash, as well as herbivorous species such as the Elm Sphinx.

All three of these habitats are present within the New Hope Floodplain as indicated by the presence of the species that belong to them. Because the rich soils in this area are essentially confined to the floodplain, the distribution of all three habitats closely coincide with the limits of the floodplain itself, even though they typically only partially overlap in other areas. As a consequence of this overlap, we treat the combination of all three types as a single habitat unit, which we refer to as the Rich Alluvial Hardwood Forests.

Currently, the NCBP has identified 214 species belonging to this combined set of habitats as they exist across the state. Seventy-six were identified during the course of the New Hope Biodiversity Survey and additional 100 have been documented in nearby areas, either in Durham County or in the four adjoining counties (see list in Appendix B). This joint habitat is one of the most distinctive biodiversity features of the New Hope Floodplain, and supports the largest number of species of conservation concern, the most exemplary of which is the Shellbark Hickory.

[3] Multi-Species Co-Determined Habitats, i.e., that are defined where multiple species strongly overlap in terms of their key habitat factors and where each species plays an equal role in defining the habitat.

In theory, any one of these 176 species could be mapped in order to delimit the extent of this habitat in the New Hope floodplain. However, some are far easier to map than others; e.g., Shellbark Hickories versus Sycamore Tussock Moths. We selected just three for detailed mapping: Shellbark Hickory, Reflexed Wild Ginger, and Smooth Yellow Violet. All three appear to be associated with the richest alluvial soils within the study area and can all be found above ground in the summer when we conducted our survey.

Mapping procedures were the same as previously described for the Shellbark Hickories and White-nymphs, both of which were recorded at the same time as the habitat survey. A map of the combined observation points for these species is shown in Figure 11. Clusters of these observations were again defined using the Aggregate Points function of ArcMap, using a 300-meter separation distance between observations as the cutoff value for inclusion. Three clusters are produced by this analysis: a large central cluster containing observation points for all three species, and two peripheral clusters containing observation points only for Reflexed Wild Ginger.

Within the central cluster, a close spatial association appears to exist between the points of all three of the targeted species, implying their underlying association with the same underlying habitat factors (none of these species is likely to be dependent on the other species themselves). The association between the points of Smooth Yellow Violets and Reflexed Wild Ginger appears to be especially strong. Using the Near function in ArcMap, the average distance from a violet location to the closest ginger location is 23 meters, with 28 out of the 43 records for the violets coinciding with a location for the ginger. The converse is not true, however, with a number of ginger locations located at long distances from the nearest violet. Although both species may be closely associated with the same habitat, differences in dispersal, past extirpation events, and habitat factors that are not shared between them probably account for the differences in their occurrence.

Although both the Smooth Yellow Violet and Reflexed Wild Ginger belong to the Rich Wet-mesic Hardwood Forests habitat – they can grow up on rich, moist slopes as well as bottomlands – they appear to grow preferentially along the edge of New Hope Creek as well the large intermittently flooded channels that penetrate widely across the floodplain. Some of those channels are indicated on the map, but there are also a number of shallower floodways that exist under the forest canopy and that have yet to be plotted. One cluster of both species was also found at the base of the slope, where no obvious flood channel exists. Neither species was found up on the slope itself, however, unlike the situation in other areas where these species are associated with Basic Mesic Forests.

A few of the Big Shellbarks were also found growing at the base of the slope on the west side of the study area but again not up on it. In general, all three species show a pattern of co-occurrence within the central cluster, with the association of the hickory closer to the wild ginger than the violet: the average distance from a Big Shellbark location to the nearest ginger is only 44 meters, compared to the 97 meters to the nearest violet.

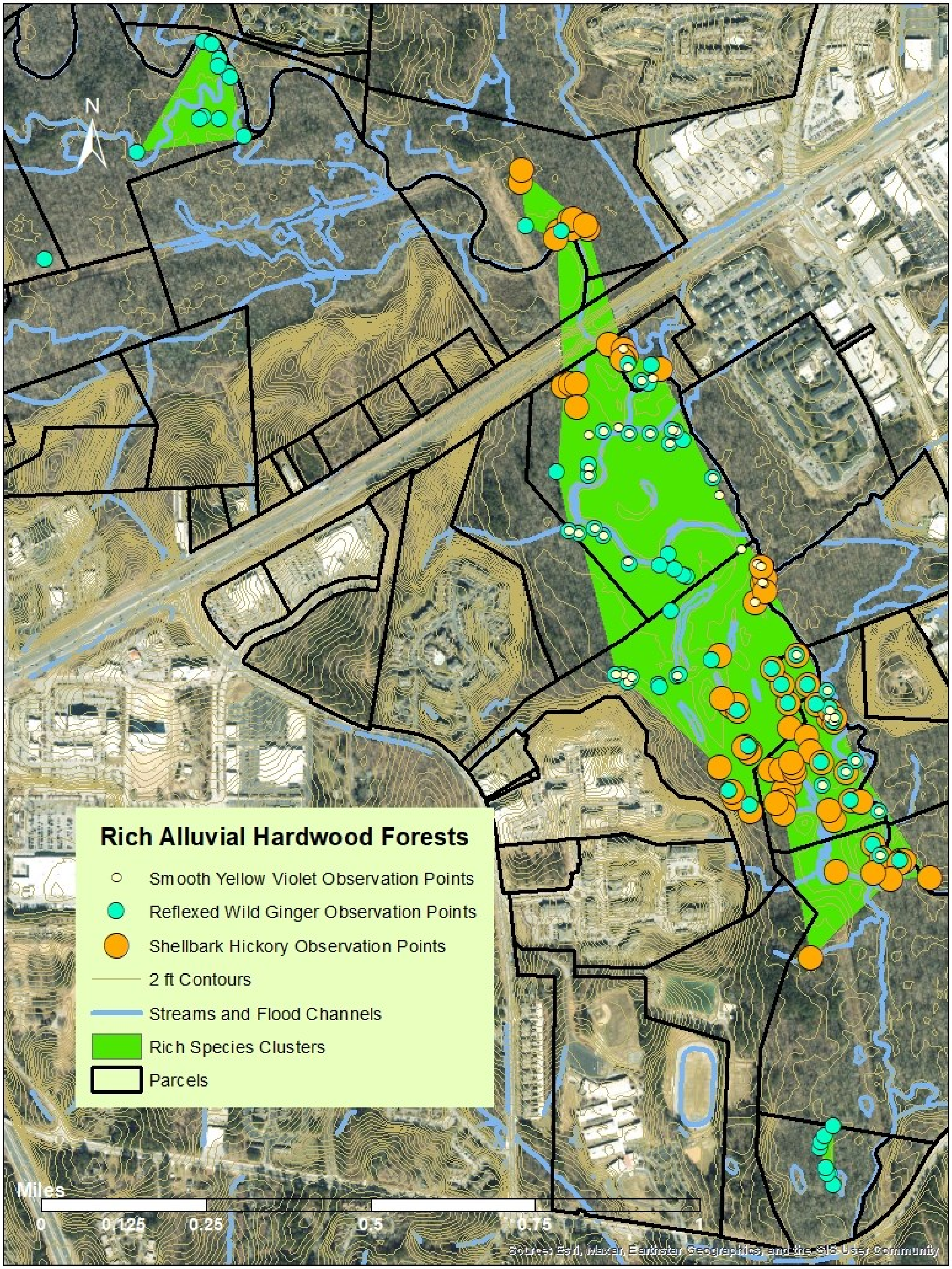


FIGURE 11. OBSERVATION POINTS AND CLUSTERS OF RICH ALLUVIAL SOIL INDICATOR SPECIES

All three of these species are known to be associated with nutrient-rich, wet-to-mesic soils (see LeGrand et al., 2023) and the pattern of their occurrences within the central cluster probably reflects the presence of rich alluvial soils deposited by flooding from the creek and extending across the floodplain by way of the flood channels, or the more general over-bank flooding in some of the lower, flatter areas of the floodplain. This relationship, however, appears to be true only for locations in the floodplain of the main stem of New Hope Creek but not to the floodplains of either Mud Creek or Dry Creek. Our hypothesis is that New Hope Creek carries a much greater load of nutrient-rich sediments than the other streams, and the headwaters of New Hope Creek do, in fact, drain a large area of mafic rock, the Meadow Flats Gabbro pluton in Orange County, as well as crossing a number of outcrops of diabase, all of which are important sources of mineral nutrients. The same does not appear to be true for the other streams, although there are at least a few small areas of mafic rock known to occur along Dry Creek.

This association between species requiring nutrient-rich and often circumneutral-to-basic soils is somewhat unusual in a bottomland context. Most of the species we have identified in this complex are, in fact, usually associated with the Basic Mesic Forest natural community (Schafale and Weakley, 1990; Schafale, 2012), which exists up on slopes that are underlain with mafic or calcareous rock outcrops. As is true for most bottomlands in the Piedmont, the soil series found in the New Hope, Mud, and Dry Creek Floodplains is mapped as Chewacla (see soils layer in the maps provided at https://maps.durhamnc.gov/). This is a fairly generic soil type consisting of deep alluvial deposits, but not characterized by any specific nutrient content or pH. In other words, the soil type is not very predictive of the specific features we observed in our study.

A closer match is the situation found along the lower floodplain (i.e., below the Fall-line) of the Roanoke River, the Tar, and other brownwater rivers that penetrate into the Coastal Plain. Along the Roanoke, in particular, very rich alluvial sediments coat the entire valley, including as far up as the crest of the bounding slopes, completely burying the acidic, nutrient-poor sandy soils that underlie them. Instead of a typical Coastal Plain flora and fauna, many of the species are more typical of the rich soil areas of the Piedmont, with some possible originating in the Ridge and Valley Province on the west side of the Blue Ridge. Although New Hope Creek is a much smaller stream, it also appears to stand out in terms of the number of species associated with rich alluvial soils. The fact that its floodplain is quite wide and is crossed by a number of sloughs, oxbows, and transient floodways – all associated with the flat expanse of the Triassic Basin lowlands – may further enhance the unique nature of this site. The depth of its alluvial substates – having accumulated for hundreds of thousands of years – may be yet another factor, particularly for such deep-rooted species as the Big Shellbark Hickory.

Soil richness, moisture, and other physical parameters may not be the only factors of importance, however, in explaining the distribution of the members of this habitat. As shown in Figure 12, the patches of Reflexed Wild Ginger and Big Shellbark Hickories extend upstream along New Hope Creek some distance north of US 15-501, indicating, as we hypothesize, the presence of deposits of rich alluvial soils. These deposits may, in fact, be as continuous as they are south of the highway and the patchiness of the plants in that area may be instead due to past land uses rather than soil type. Figure 12 shows the observation points for Reflexed Wild Ginger overlain on a 1972 aerial photo, which shows both the highway and powerline corridor that were constructed somewhat earlier.

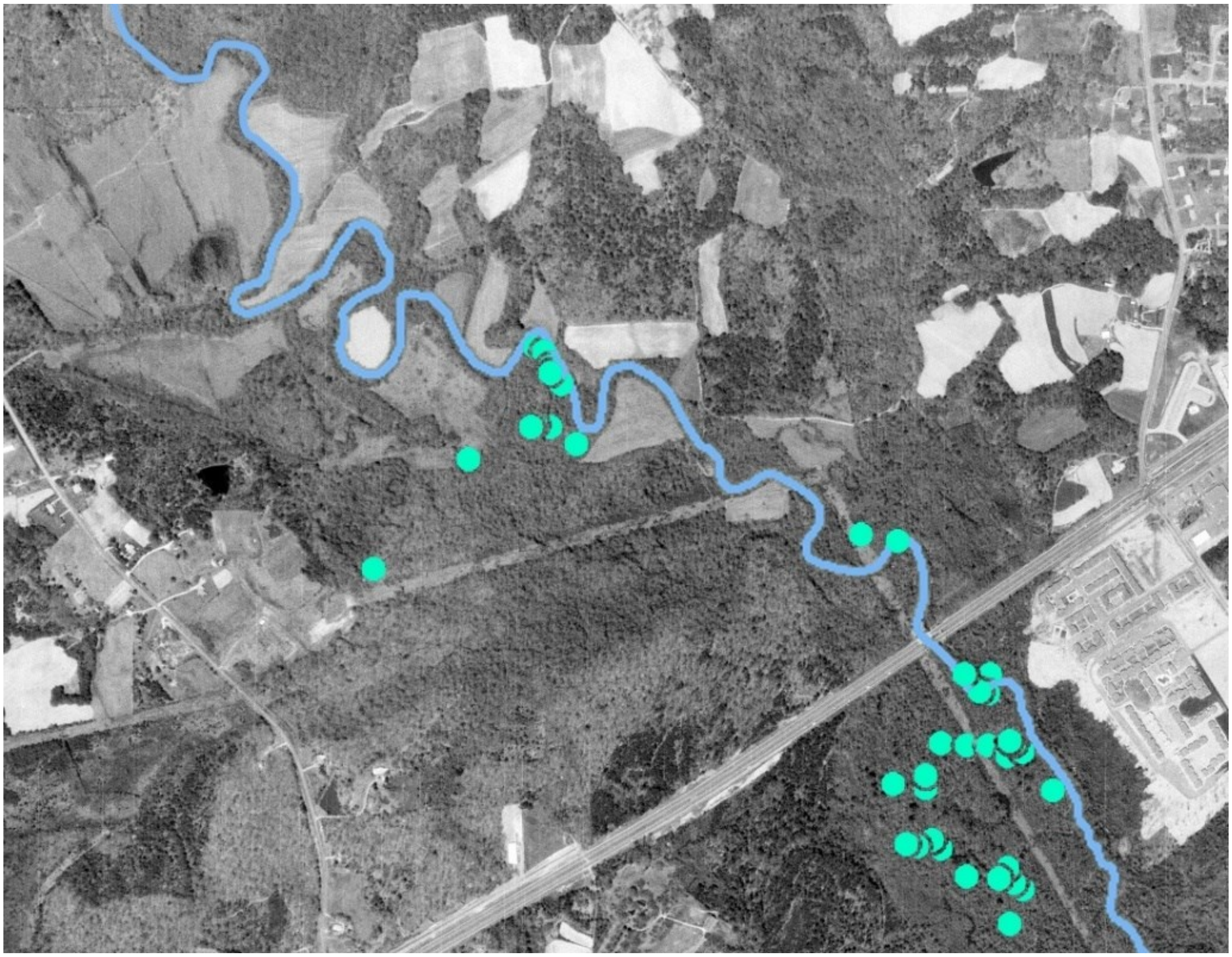


FIGURE 12. FOREST COVER IN 1972 AND CURRENT LOCATION OF REFLEXED WILD GINGER

As shown, the observation points are all located in areas that have had a well-developed forest cover for at least the past 50 years, with none of these points falling within even nearby areas that had been used for pasture or cultivation as late as 1972 (these same tracts were also shown as forested in a 1955 aerial photo and mostly in the 1940 aerial photo previously shown). Based on this information, we believe that a combination of rich soils and a long-term presence of hardwood forest cover may best explain the current distribution of the members of Rich Alluvial Hardwood Forests habitat (note that this complicates our interpretation of the absence of members of this habitat in the Mud Creek and Dry Creek floodplains, where both factors may play some role).

Conservation Recommendations

The Big Shellbark Hickory remains the species of greatest conservation concern in the New Hope Floodplain. Although this status was challenged by the White-nymph, which appeared to be even more restricted in the state, the results of this survey, plus information supplied by David Bradley, strongly suggest that it is a recent, weedy arrival rather than a significantly imperiled species. Given the importance of this species to biodiversity conservation in North Carolina, we have a number of conservation recommendations aimed specifically at this species.

Recommended Conservation Actions for the Big Shellbark Hickory

1) The key goal is to protect as many individuals of the species and as much of its existing range as possible: the more individuals there are and the larger the range, the more likely a species is to avoid complete extirpation during a given mass mortality event and the quicker it is likely to recover. This requires that as many individuals and patches are documented as possible. More thorough surveys of its distribution in the New Hope Floodplain are consequently needed. Priority areas for survey include privately-owned lands that were left out of the survey, especially Parcels 206066, 140089, and 140087. Several areas of the Game Lands were also not surveyed, including Parcels 140085, 140081 and the southwest portions of 140077. Surveys should also be extended into the Game Lands south of Old Chapel Hill Road. Wherever stands of Big Shellbarks occur in these areas, an effort should be made to bring them into conservation protection. In addition to outright acquisition, conservation easements and management agreements with the landowners should be sought.
2) Seedlings of this species appear to be vulnerable to deer over-browsing as well as competition with Chinese Privet and possibly other invasive shrubs (Chafin, 2020). Although we found a substantial number of young trees, we did not record any seedlings or transgressives, which along with the slow maturation of this species and possible restricted dispersal of its very large and heavy nuts, may be a factor limiting its apparent ongoing recovery from some past near-extirpation event. While these factors need more investigation – as do the causes for any past extirpations that have taken place – there are several practical steps that can be taken to increase the survival of young Shellbarks. These include allowing hunting on some of the tracts, especially north of the highway. Use of deer exclosures should also be considered around clusters of seedlings, if found, as should clearing of privet in any areas supporting or potentially supporting this species. See Thyroff et al. (2022) for a discussion of tree shelter techniques used to reduce deer impacts in reforestation projects.
3) Gathering nuts and propagating them in controlled circumstances and then planting them once they have reached a certain level of maturity could also help, as would planting them in areas of currently unoccupied habitat, such as the areas of rich alluvial soils indicated by the presence of Reflexed Wild Ginger. Banking of seeds would also help in the restoration of the population following any of the increasingly likely mortality events that will result due to climate change. See Cobb et al. (2020) and Luna et al. (2014) for propagation methods.
4) As discussed in the 2021-22 report, the use of herbicides to suppress woody vegetation underneath the powerline that runs through much of this area may be having extensive non-target impacts. Given the water solubility of the glyphosates used in many of these compounds, floodwaters crossing the powerline have some potential for carrying these chemicals widely across the floodplain. Given the concentration of Big Shellbarks along some of these watercourses, they potentially could be exposed to their effects, with seedlings probably the most at risk. Curtailing the use of these herbicides within the natural area could therefore be highly beneficial. Conducting bioassays for the effects of these herbicides specifically on seedling Big Shellbarks would help make the case for a change in management, at least in areas located adjacent to the powerline.

5) With a map now in hand showing the location of Big Shellbarks quite close to US 15-501, it seems very clear that the final preferred route of the now-abandoned Light Rail Transit could have eliminated most, if not all of those individuals. Any new proposals for infrastructure projects located within the New Hope floodplain should be evaluated with respect to their impacts to this species.

While the Big Shellbark continues to deserve special consideration, the results of this survey point to the importance of considering the habitat relationships not only of this species, but of 75 additional species that have been recorded in the floodplain in association with its extensive, rich alluvial soils. Conservation efforts focused on the Big Shellbark should benefit most, if not all, of these associated species but efforts to preserve and improve the conditions supporting this entire set of species are likely to produce even greater ecological benefits, including to the Big Shellbark Hickory itself.

<u>Recommended Conservation Actions for the Rich Alluvial Forest Habitat</u>

1) The same need for more surveys described above for the Big Shellbark is also true for occurrences of the habitat to which it belongs: the greater the number and extent of the habitat occurrences, the more likely all the species that belong to this habitat will be able to resist and recover from extirpation events. The same Parcels identified as priorities for further surveys for the Big Shellbark Hickory are also the priorities for surveying for additional units of the habitat, whether or not the Big Shellbarks occur within them.
2) The goal of habitat conservation is to reduce the probabilities of extirpation of all the species that belong to them. The overall number of extirpations expected within a period of time is equal to the sum of the probabilities of extirpation within that period for the individual species. For many of the plant species of the Rich Alluvial Forests, the same management recommendations apply that were made for the Big Shellbark Hickory, particularly reducing the impacts of deer over-browsing and competition or predation by invasive species such as privet and Japanese Stilt Grass. Reduction of the impacts from those causes will also indirectly benefit all of the herbivores that feed on those species, many of which are tightly associated with these habitats. Measures that directly benefit those animal species themselves will also benefit the entire habitat. Such measures include reducing the impacts of light pollution and the increased flood frequency and duration that appear to be having major impacts on the animal species belonging to this habitat, which make up 42% of the total number of its species.
3) Reducing the expected number of extirpations is not the only goal of conservation; another is to maintain the overall integrity of the habitat. The measure we use for integrity is the ratio of species that are expected to occur within a given habitat to those that are actually still present. In the case of the occurrence of the Rich Alluvial Forest habitat along New Hope Creek, the ratio of the number of species actually observed during the recent surveys to the sum of that number and those that were failed to find is

   76 / (76+100) = 43%

   That ratio can be improved – an important goal of biodiversity conservation -- if populations of the missing species are either discovered as the result of new surveys or if the species otherwise return to the project area. That last possibility can occur either naturally, by dispersal of the species into the New Hope Creek Floodplain, or by artificial re-introduction. In the case of the species missing from this particular area, those that were documented within the area but are now considered Historic are the ones most likely to return on their own but would also be good candidates for re-introduction. These include two butterfly species, the Tawny Emperor (*Asterocampa clyton*) and Falcate Orange-tip (*Anthocharis midea*), and two vascular plants, Wild Geranium (*Geranium maculatum*) and Yellow Lady-slipper (*Cypripedium parviflorum*). In the case of the vanished plant species, re-introductions would make sense only if the factors that led to their loss have been reduced or eliminated via conservation management, deer over-browsing particularly in the case of the Lady-slipper. In any case, recovery/rediscovery of these four species would change the habitat integrity ratio to 45%, a small amount but nonetheless a positive conservation achievement.

Other Habitats

Although we only had time in this survey to cover just this one group of habitats – which we consider to be the most distinctive of the New Hope Floodplain in Durham County – this same approach can be used for all of the remaining 89 habitats that were listed for the study area in the New Hope Biodiversity Project website (see the Habitats menu item on https://auth1.dpr.ncparks.gov/ncbp_neho/index.php). We believe that a habitat-based approach will ultimately be one of the most effective ways of dealing with the complexity of biodiversity conservation, taking into account the enormous array of both species and other taxonomic groups as well as the still larger number of ecological relationships that are the foundation of stable ecosystems. As discussed for the Rich Alluvial Hardwood Forests group, conservation measures aimed at entire habitats will benefit all members of that habitat, including those that are in the greatest need of conservation. Conversely, understanding the habitat needs of the most imperiled species in a particular habitat will provide information not only useful for the conservation of those individual species but all of the others that share the same habitat. We thus regard a combination of habitat-focused approaches and species-focused approaches as optimal for dealing with these very complex and increasingly critical conservation issues.

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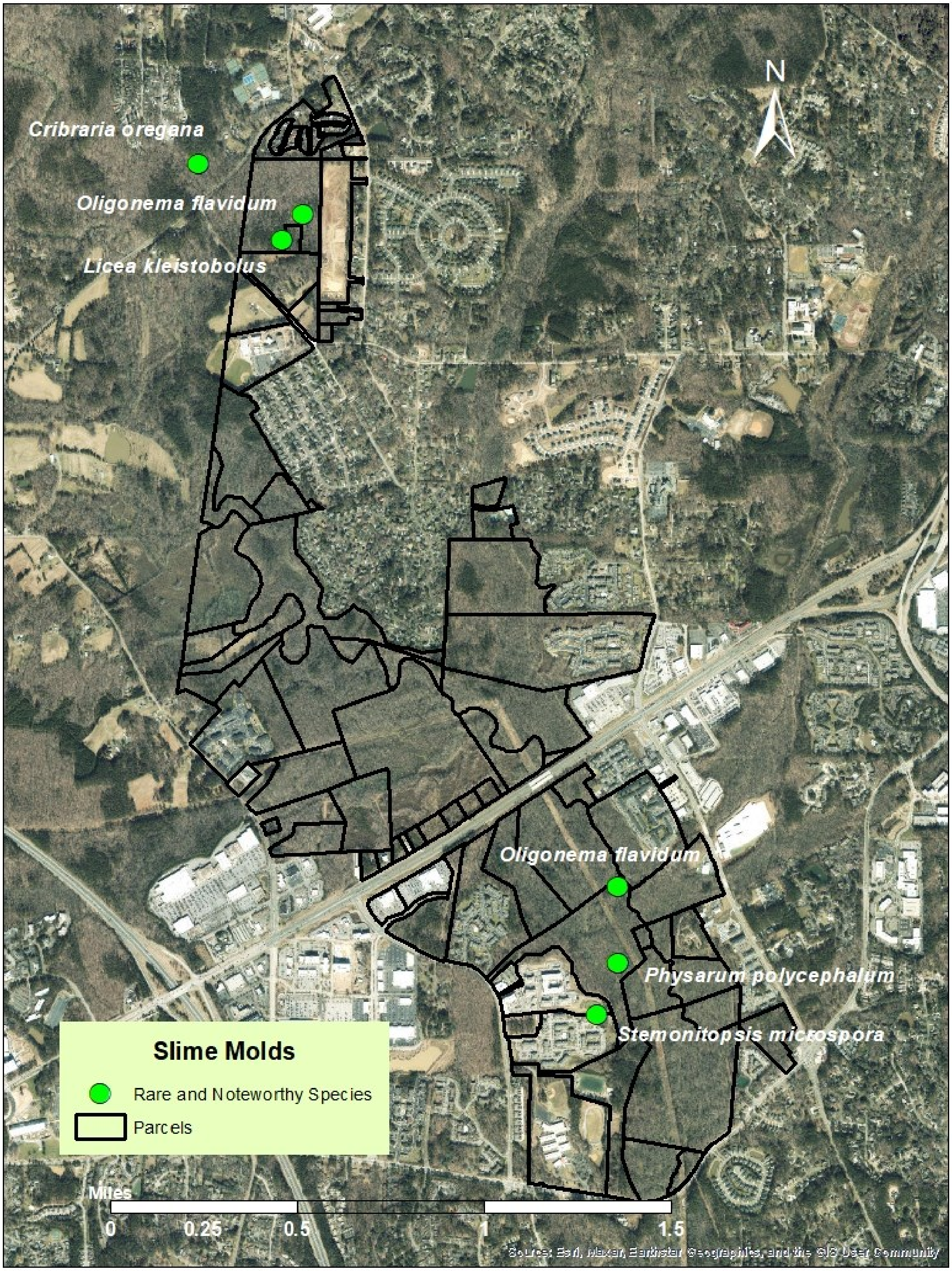
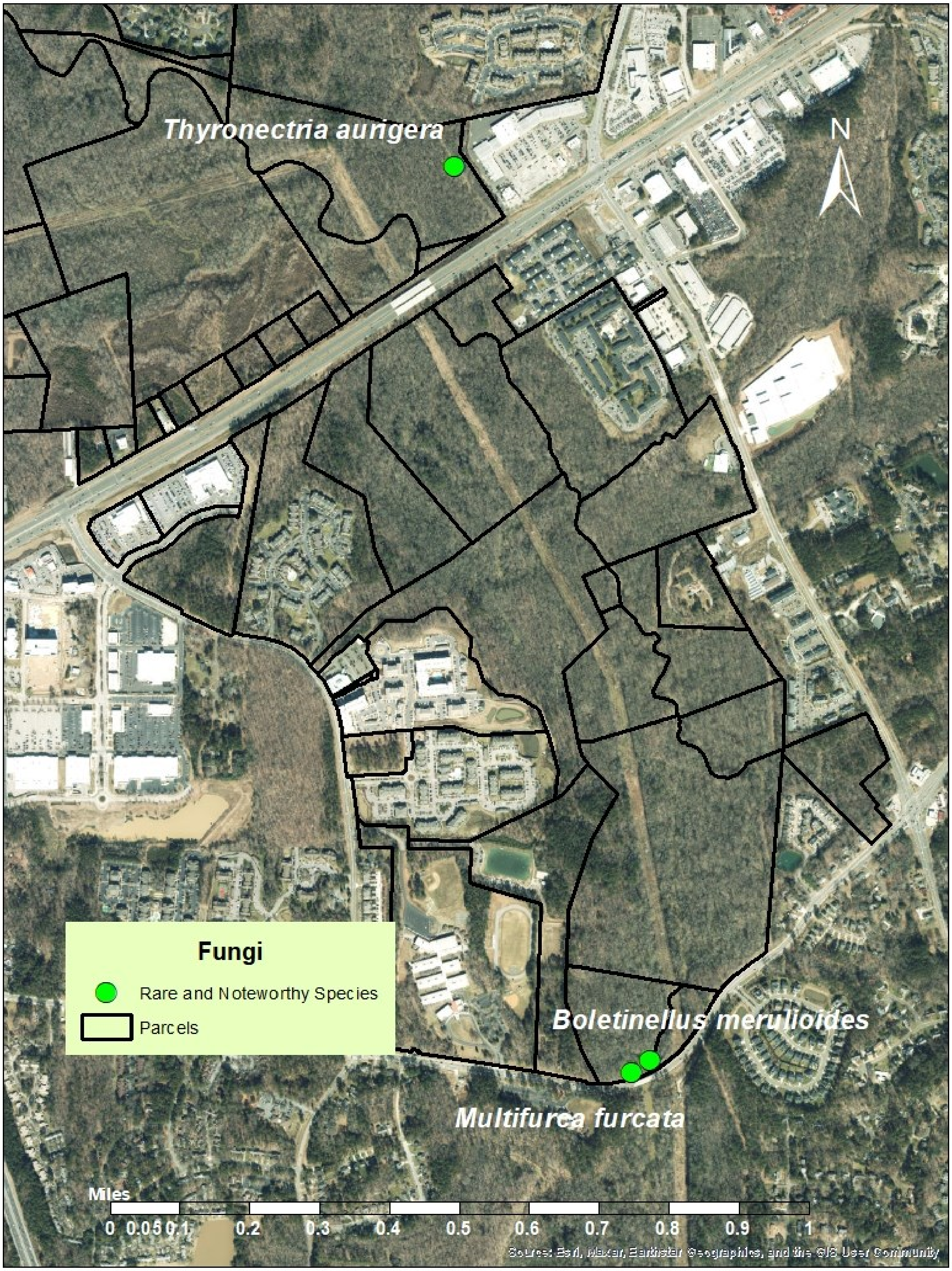
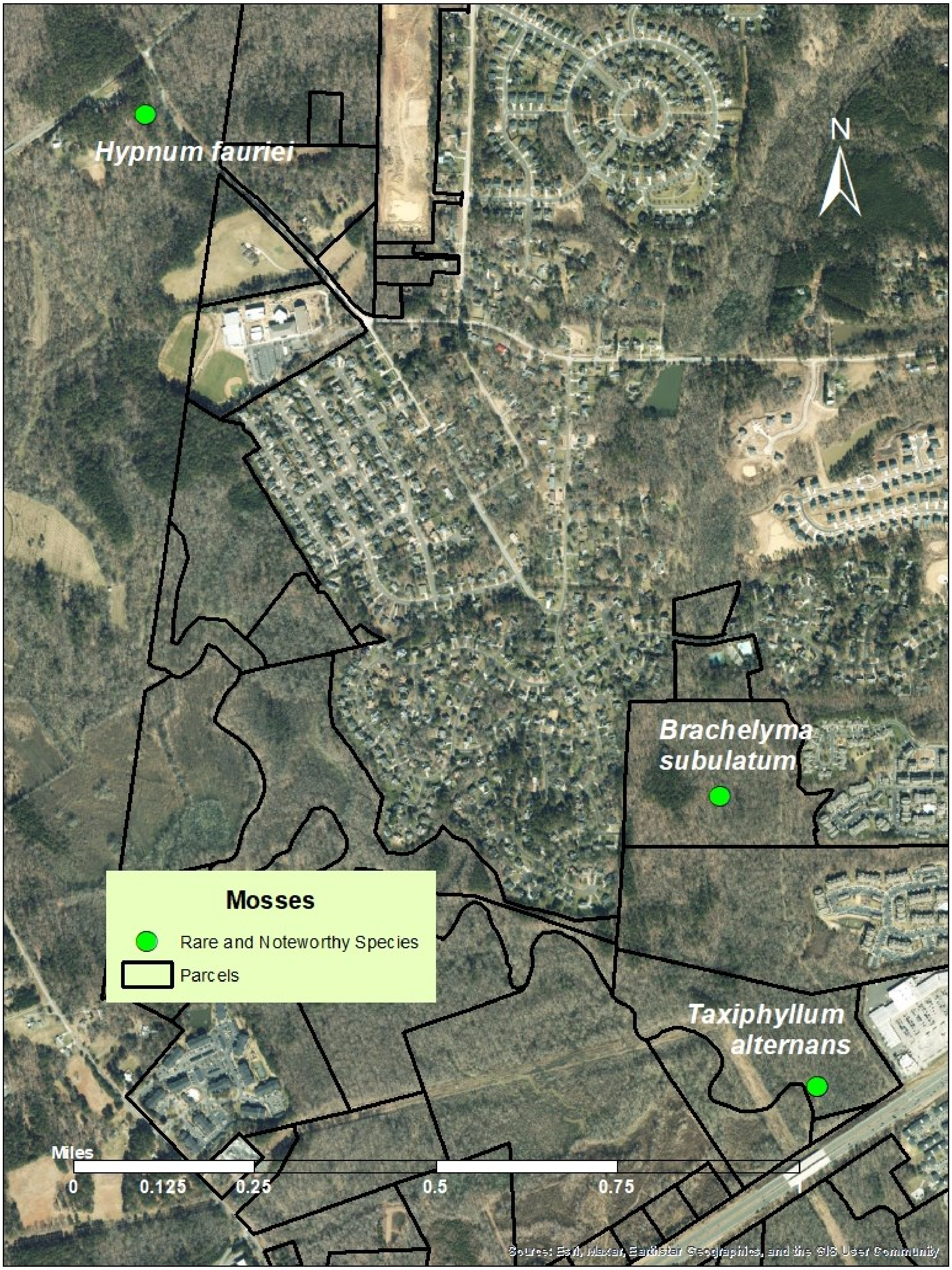
Appendix A. Maps of Rare Species Recorded in the 2021-22 Inventory

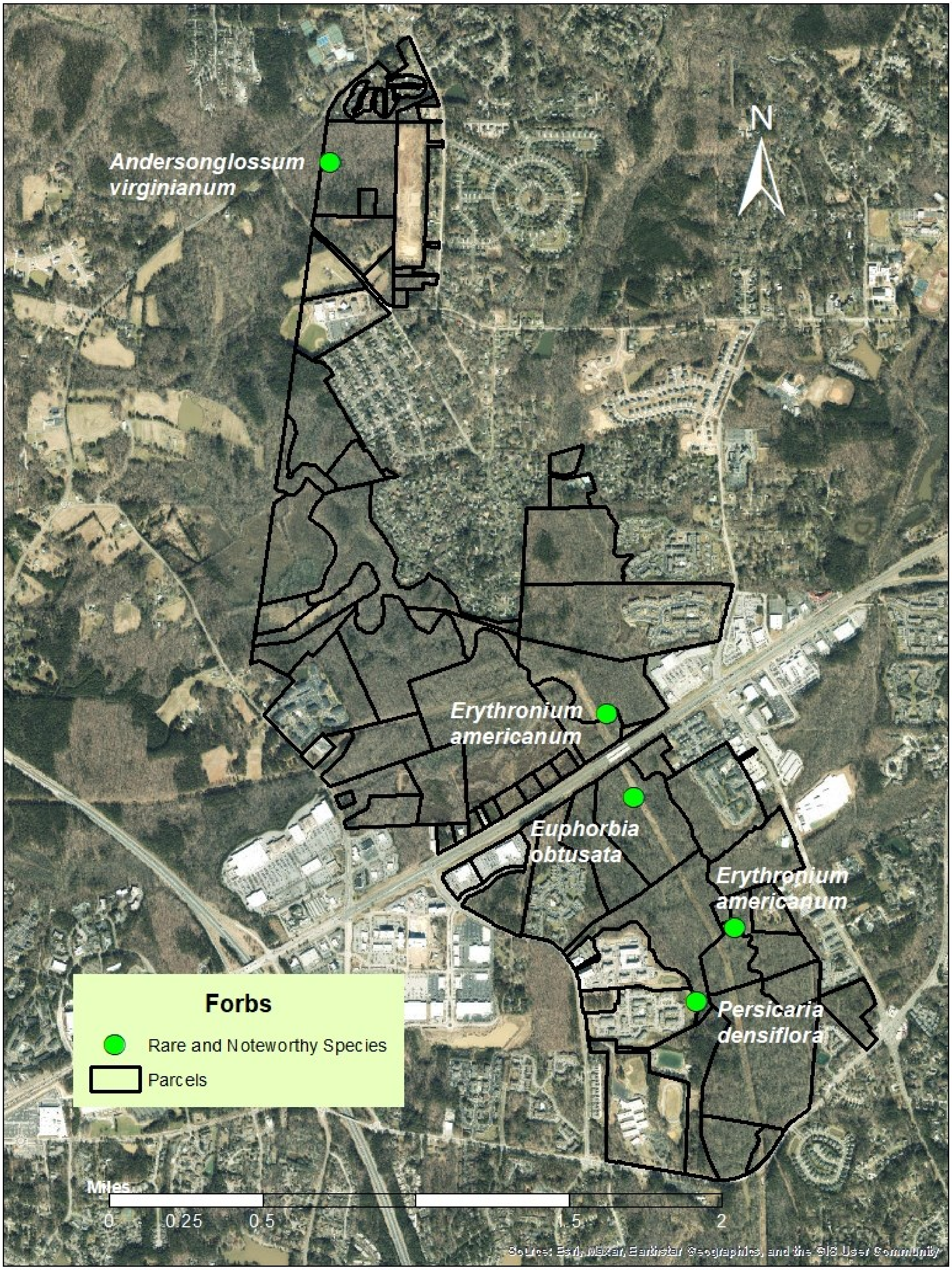



Thyronectria aurigera
N
Fungi
Rare and Noteworthy Species
Parcels
Boletinellus merulioides
Multifurca furcata
Miles
0 0.05 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

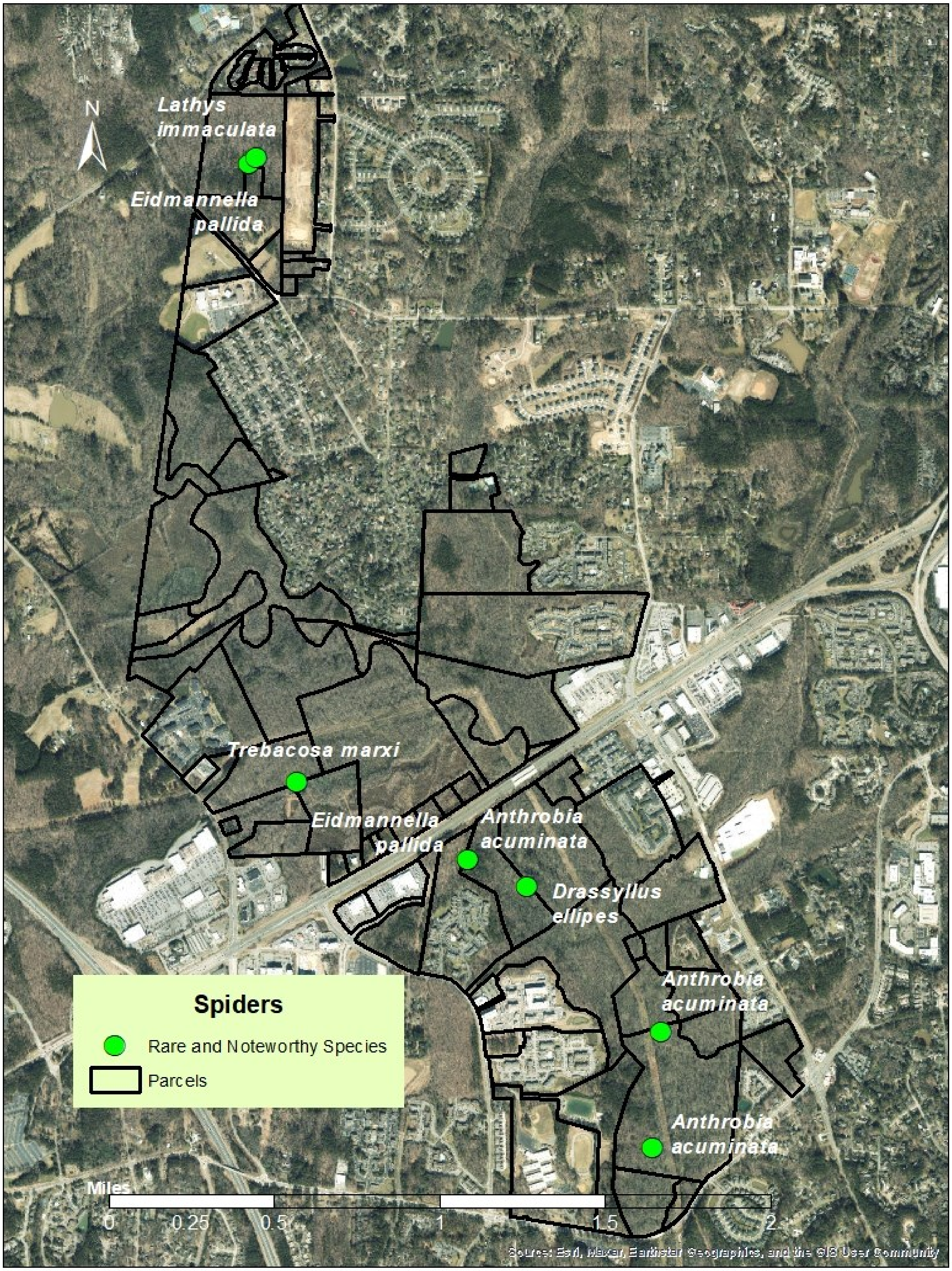
Scytinium lichenoides
Bacidia purpurans
Bacidina delicata
Micarea soralifera
Calicium salicinum
N
Lichens
Rare and Noteworthy Species
Parcels
Miles
0 0.05 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

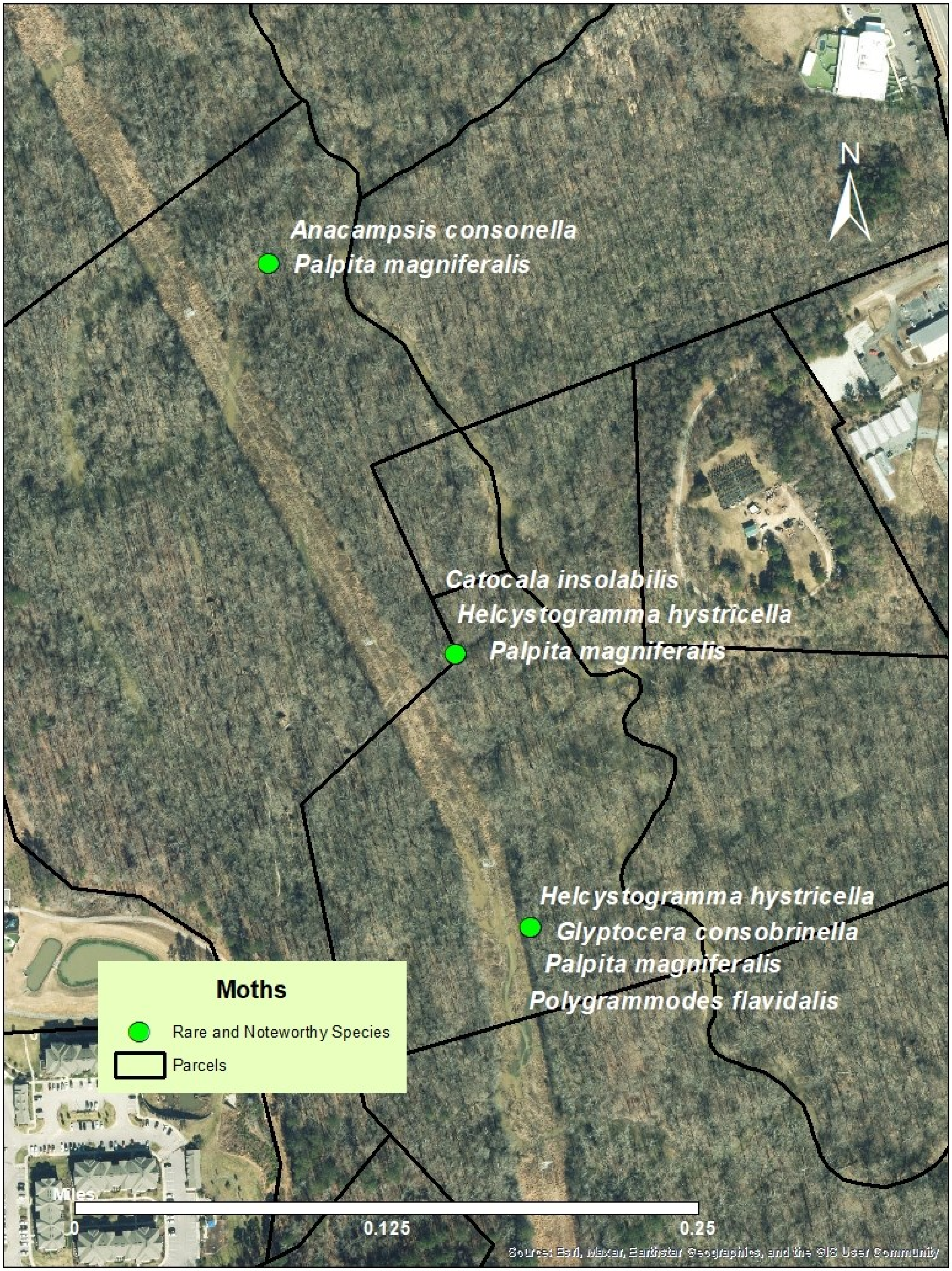


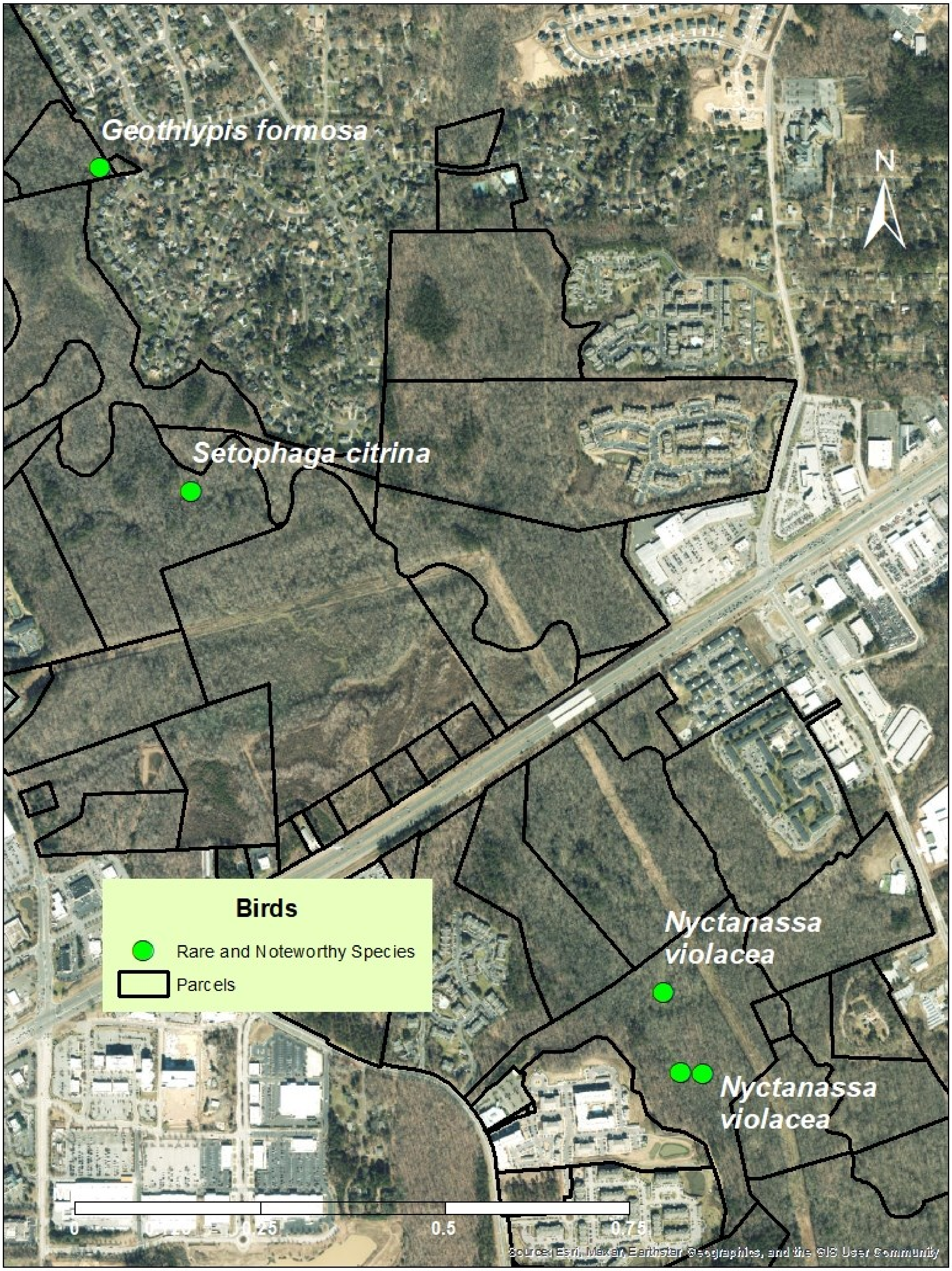
Hypnum fauriei
N
Brachelyma subulatum
Mosses
Rare and Noteworthy Species
Parcels
Taxiphyllum alternans
Miles
0
0.125
0.25
0.5
0.75
1
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community


Andersonglossum virginianum
N
Erythronium americanum
Euphorbia obtusata
Erythronium americanum
Persicaria densiflora
Forbs
Rare and Noteworthy Species
Parcels
Miles
0 0.25 0.5 1 1.5 2
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community


Glyceria septentrionalis
N
Grasses
Rare and Noteworthy Species
Parcels
Miles
0
0.05
0.1
0.2
0.3
0.4
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community


N
Lathys immaculata
Eidmannella pallida
Trebacosa marxi
Eidmannella pallida
Anthrobia acuminata
Drassyllus ellipes
Anthrobia acuminata
Anthrobia acuminata
Spiders
Rare and Noteworthy Species
Parcels
Miles
0
0.25
0.5
1
1.5
2
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community


Anacampsis consonella
Palpita magniferalis
Catocala insolabilis
Helcystogramma hystricella
Palpita magniferalis
Helcystogramma hystricella
Glyptocera consobrinella
Palpita magniferalis
Polygrammodes flavidalis
N
Moths
Rare and Noteworthy Species
Parcels
Miles
0
0.125
0.25
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Geothlypis formosa
Setophaga citrina
N
Birds
Rare and Noteworthy Species
Parcels
Nyctanassa violacea
Nyctanassa violacea
0
0.25
0.5
0.75

Appendix B. Species Associated with Rich Alluvial Forests

Observed – + Recorded in the New Hope Floodplain; H Historic in the NHF
Failed to Find – Not found in the survey but present in nearby areas

Habitat	Taxon	Scientific Name	State Rank	Observed	Failed to Find
Rich Wet Hardwood Forests	HEMIPTERAN HOPPERS	*Eratoneura hymettana*	SNR		+
Rich Wet Hardwood Forests	HEMIPTERAN HOPPERS	*Eratoneura morgani*	SNR		+
Rich Wet Hardwood Forests	HEMIPTERAN HOPPERS	*Scaphoideus crassus*	SNR		+
Rich Wet Hardwood Forests	MOTHS	*Adoxophyes furcatana*	SU		
Rich Wet Hardwood Forests	MOTHS	*Adoxophyes negundana*	S3S4		
Rich Wet Hardwood Forests	MOTHS	*Ancylis platanana*	S3S5		+
Rich Wet Hardwood Forests	MOTHS	*Caloptilia negundella*	S3S4	+	
Rich Wet Hardwood Forests	MOTHS	*Cosmopterix clandestinella*	S2	+	
Rich Wet Hardwood Forests	MOTHS	*Ectoedemia clemensella*	S3S4		+
Rich Wet Hardwood Forests	MOTHS	*Ectoedemia platanella*	S3S4	+	
Rich Wet Hardwood Forests	MOTHS	*Gelechia albisparsella*	S1S3		
Rich Wet Hardwood Forests	MOTHS	*Halysidota harrisii*	S4		+
Rich Wet Hardwood Forests	MOTHS	*Lithophane signosa*	S3S4		
Rich Wet Hardwood Forests	MOTHS	*Misogada unicolor*	S4S5		+
Rich Wet Hardwood Forests	MOTHS	*Pococera militella*	S3S4		+
Rich Wet Hardwood Forests	MOTHS	*Proteoteras willingana*	S2S4		
Rich Wet Hardwood Forests	MOTHS	*Theisoa constrictella*	S3S4		+
Rich Wet Hardwood Forests	MOTHS	*Zale galbanata*	S4	+	
Rich Wet Hardwood Forests	FORBS	*Rudbeckia laciniata*	S5		+
Rich Wet Hardwood Forests	FORBS	*Trillium recurvatum*	S1		
Rich Wet Hardwood Forests	GRAMINOIDS	*Carex amphibola*	S5	+	
Rich Wet Hardwood Forests	GRAMINOIDS	*Carex cherokeensis*	S1S2		+
Rich Wet Hardwood Forests	GRAMINOIDS	*Carex grayi*	S4	+	
Rich Wet Hardwood Forests	GRAMINOIDS	*Carex squarrosa*	S3	+	
Rich Wet Hardwood Forests	GRAMINOIDS	*Carex tribuloides*	S4	+	
Rich Wet Hardwood Forests	GRAMINOIDS	*Carex typhina*	S4	+	
Rich Wet Hardwood Forests	GRAMINOIDS	*Dichanthelium clandestinum*	S4	+	
Rich Wet Hardwood Forests	VINES	*Clematis virginiana*	S5	+	
Rich Wet Hardwood Forests	VINES	*Smilax pulverulenta*	S4		+
Rich Wet Hardwood Forests	HARDWOOD TREES	*Acer negundo*	S5	+	
Rich Wet Hardwood Forests	HARDWOOD TREES	*Acer saccharinum*	S3		+
Rich Wet Hardwood Forests	HARDWOOD TREES	*Carya laciniosa*	S1	+	
Rich Wet Hardwood Forests	HARDWOOD TREES	*Fraxinus pennsylvanica*	S5	+	
Rich Wet Hardwood Forests	HARDWOOD TREES	*Platanus occidentalis*	S5	+	
Rich Wet Hardwood Forests	HARDWOOD TREES	*Populus deltoides*	S4	+	
Rich Wet Hardwood Forests	HARDWOOD TREES	*Quercus bicolor*	S2		+
Rich Wet Hardwood Forests	HARDWOOD TREES	*Quercus michauxii*	S5	+	

Habitat	Taxon	Scientific Name	State Rank	Observed	Failed to Find
Rich Wet Hardwood Forests	HARDWOOD TREES	*Quercus shumardii*	S4	+	
Rich Wet Hardwood Forests	HARDWOOD TREES	*Ulmus americana*	S5	+	
Rich Wet-Dry Hardwood Forests	BUTTERFLIES	*Asterocampa celtis*	S5	+	
Rich Wet-Dry Hardwood Forests	BUTTERFLIES	*Asterocampa clyton*	S4	H	+
Rich Wet-Dry Hardwood Forests	BUTTERFLIES	*Heraclides cresphontes*	S2S3		
Rich Wet-Dry Hardwood Forests	BUTTERFLIES	*Libytheana carinenta*	S5	+	
Rich Wet-Dry Hardwood Forests	MOTHS	*Acrobasis ostryella*	SU		
Rich Wet-Dry Hardwood Forests	MOTHS	*Acronicta interrupta*	S3S4	+	
Rich Wet-Dry Hardwood Forests	MOTHS	*Acronicta rubricoma*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Acronicta vinnula*	S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Catocala angusi*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Catocala obscura*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Catocala residua*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Catocala robinsonii*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Ceratomia amyntor*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Heterocampa subrotata*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Isogona tenuis*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Norape cretata*	S3S4		+
Rich Wet-Dry Hardwood Forests	MOTHS	*Phyllonorycter celtifoliella*	S2	+	
Rich Wet-Dry Hardwood Forests	MOTHS	*Phyllonorycter celtisella*	S2	+	
Rich Wet-Dry Hardwood Forests	MOTHS	*Sciota celtidella*	S3S4	+	
Rich Wet-Dry Hardwood Forests	FORBS	*Aquilegia canadensis*	S5		+
Rich Wet-Dry Hardwood Forests	FORBS	*Cubelium concolor*	S3		+
Rich Wet-Dry Hardwood Forests	SHRUBS	*Ptelea trifoliata*	S3		+
Rich Wet-Dry Hardwood Forests	HARDWOOD TREES	*Celtis occidentalis*	S2		+
Rich Wet-Dry Hardwood Forests	HARDWOOD TREES	*Celtis smallii*	S4		
Rich Wet-Mesic Hardwood Forests	BIRDS	*Geothlypis formosa*	S3S4	+	
Rich Wet-Mesic Hardwood Forests	HEMIPTERAN HOPPERS	*Dikrella maculata*	SNR		+
Rich Wet-Mesic Hardwood Forests	HEMIPTERAN HOPPERS	*Pediopsoides distinctus*	SNR		+
Rich Wet-Mesic Hardwood Forests	BUTTERFLIES	*Amblyscirtes hegon*	S4		+
Rich Wet-Mesic Hardwood Forests	BUTTERFLIES	*Anthocharis midea*	S5	H	+
Rich Wet-Mesic Hardwood Forests	BUTTERFLIES	*Eurytides marcellus*	S5	+	
Rich Wet-Mesic Hardwood Forests	BUTTERFLIES	*Lethe anthedon*	S4		+
Rich Wet-Mesic Hardwood Forests	BUTTERFLIES	*Polygonia comma*	S5	+	
Rich Wet-Mesic Hardwood Forests	BUTTERFLIES	*Polygonia interrogationis*	S5	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Acrobasis demotella*	S3S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Acrobasis juglandis*	S2S3		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Acrobasis latifasciella*	S2S3		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Acronicta hamamelis*	S3S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Acronicta morula*	S3S4	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Baileya australis*	S4S5		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Baileya dormitans*	S4S5	+	

Habitat	Taxon	Scientific Name	State Rank	Observed	Failed to Find
Rich Wet-Mesic Hardwood Forests	MOTHS	*Baileya levitans*	S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Besma endropiaria*	S5		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Bucculatrix polymniae*	S2S3		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Caloptilia blandella*	S3S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Cameraria aesculisella*	S2	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Canarsia ulmiarrosorella*	S3S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catastega aceriella*	S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catocala agrippina*	S2S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catocala luctuosa*	S1		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catocala maestosa*	S3S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catocala nebulosa*	S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catocala neogama*	S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catocala orba*	S2S3		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catocala piatrix*	S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Catocala subnata*	S3S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Cosmopterix teligera*	S1S3	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Dypterygia rozmani*	S3S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Ecdytolopha mana*	S3S4	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Glaucolepis saccharella*	S2S3	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Helcystogramma hystricella*	S2S3	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Hypena abalienalis*	S3S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Hypena humuli*	S3S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Hypena madefactalis*	S4S5		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Hypena sordidula*	S3S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Nerice bidentata*	S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Omphalocera cariosa*	S2S3	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Omphalocera munroei*	S3S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Papaipema polymniae*	SU		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Papaipema rutila*	S2S3		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Peridea basitriens*	S4	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Phyllonorycter lucidicostella*	S2	+	
Rich Wet-Mesic Hardwood Forests	MOTHS	*Scopula ordinata*	S3S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Talponia plummeriana*	S2S4		
Rich Wet-Mesic Hardwood Forests	MOTHS	*Trigrammia quadrinotaria*	S4		+
Rich Wet-Mesic Hardwood Forests	MOTHS	*Zeiraphera claypoleana*	S2S4		+
Rich Wet-Mesic Hardwood Forests	BEES	*Andrena erigeniae*	S3S4	+	
Rich Wet-Mesic Hardwood Forests	FERNS	*Adiantum pedatum*	S5		+
Rich Wet-Mesic Hardwood Forests	FERNS	*Amauropelta noveboracensis*	S5	+	
Rich Wet-Mesic Hardwood Forests	FERNS	*Athyrium asplenioides*	S5	+	
Rich Wet-Mesic Hardwood Forests	FERNS	*Phegopteris hexagonoptera*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Aconitum uncinatum*	S3S4		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Actaea pachypoda*	S4		+

Habitat	Taxon	Scientific Name	State Rank	Observed	Failed to Find
Rich Wet-Mesic Hardwood Forests	FORBS	*Actaea racemosa*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Amsonia tabernaemontana*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Arisaema dracontium*	S3S4	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Aruncus dioicus*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Asarum reflexum*	S4S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Cardamine concatenata*	S4	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Cardamine diphylla*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Cardamine dissecta*	S2		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Cardamine douglassii*	S2		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Caulophyllum thalictroides*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Chaerophyllum procumbens*	S3	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Circaea canadensis*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Claytonia virginica*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Collinsonia canadensis*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Collinsonia tuberosa*	S1S2		
Rich Wet-Mesic Hardwood Forests	FORBS	*Coreopsis tripteris*	S4		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Corydalis flavula*	S4	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Cryptotaenia canadensis*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Cypripedium parviflorum*	S3	H	+
Rich Wet-Mesic Hardwood Forests	FORBS	*Delphinium tricorne*	S3		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Dicentra cucullaria*	S4	+	+
Rich Wet-Mesic Hardwood Forests	FORBS	*Erigenia bulbosa*	S1		
Rich Wet-Mesic Hardwood Forests	FORBS	*Erythronium americanum*	S3	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Euonymus atropurpureus*	S2		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Euphorbia obtusata*	S3	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Eurybia mirabilis*	S3		
Rich Wet-Mesic Hardwood Forests	FORBS	*Galearis spectabilis*	S4		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Geranium maculatum*	S5	H	+
Rich Wet-Mesic Hardwood Forests	FORBS	*Geum canadense*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Geum virginianum*	S4		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Hylodesmum glutinosum*	S3		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Iris cristata*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Laportea canadensis*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Mertensia virginica*	S2		
Rich Wet-Mesic Hardwood Forests	FORBS	*Nanopanax trifolius*	S2S3		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Panax quinquefolius*	S3S4		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Persicaria virginiana*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Phlox divaricata*	S3		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Phryma leptostachya*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Podophyllum peltatum*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Polemonium reptans*	S1		
Rich Wet-Mesic Hardwood Forests	FORBS	*Primula meadia*	S2S3		

Habitat	Taxon	Scientific Name	State Rank	Observed	Failed to Find
Rich Wet-Mesic Hardwood Forests	FORBS	*Ranunculus hispidus*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Ranunculus micranthus*	S1		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Sanguinaria canadensis*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Scrophularia marilandica*	S4		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Smallanthus uvedalia*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Steironema ciliatum*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Symphyotrichum phlogifolium*	S3		
Rich Wet-Mesic Hardwood Forests	FORBS	*Thaspium barbinode*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Tiarella cordifolia*	S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Tradescantia virginiana*	S2S3		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Trillium cuneatum*	S3		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Trillium rugelii*	S3		
Rich Wet-Mesic Hardwood Forests	FORBS	*Viola eriocarpa*	S5	+	
Rich Wet-Mesic Hardwood Forests	FORBS	*Viola striata*	S4S5		+
Rich Wet-Mesic Hardwood Forests	FORBS	*Viola walteri*	S1		
Rich Wet-Mesic Hardwood Forests	AQUATIC FORBS	*Hydrophyllum canadense*	S4		+
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Bromus pubescens*	S4		+
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Carex blanda*	S4	+	
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Carex bromoides ssp. bromoides*	S3		+
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Carex crebriflora*	S3		+
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Carex granularis*	S2S3		+
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Chasmanthium latifolium*	S4	+	
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Elymus hystrix*	S4	+	
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Elymus macgregorii*	S3		
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Leersia virginica*	S5	+	
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Luzula acuminata*	S4		+
Rich Wet-Mesic Hardwood Forests	GRAMINOIDS	*Poa cuspidata*	S4		+
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Aesculus sylvatica*	S5	+	
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Asimina triloba*	S5	+	
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Swida alternifolia*	S4		+
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Crataegus spathulata*	S1S2		
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Dirca palustris*	S3		+
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Lindera benzoin*	S5	+	
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Philadelphus inodorus*	S3		
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Staphylea trifolia*	S4	+	
Rich Wet-Mesic Hardwood Forests	SHRUBS	*Viburnum prunifolium*	S5	+	
Rich Wet-Mesic Hardwood Forests	VINES	*Ampelopsis cordata*	S2		
Rich Wet-Mesic Hardwood Forests	VINES	*Dioscorea quaternata*	S4		+
Rich Wet-Mesic Hardwood Forests	VINES	*Menispermum canadense*	S4	+	
Rich Wet-Mesic Hardwood Forests	VINES	*Smilax herbacea*	S4		+
Rich Wet-Mesic Hardwood Forests	VINES	*Smilax hispida*	S5	+	

Habitat	Taxon	Scientific Name	State Rank	Observed	Failed to Find
Rich Wet-Mesic Hardwood Forests	VINES	*Vitis labrusca*	S4		+
Rich Wet-Mesic Hardwood Forests	VINES	*Vitis riparia*	S2		
Rich Wet-Mesic Hardwood Forests	HARDWOOD TREES	*Acer floridanum*	S5	+	
Rich Wet-Mesic Hardwood Forests	HARDWOOD TREES	*Carya cordiformis*	S4	+	
Rich Wet-Mesic Hardwood Forests	HARDWOOD TREES	*Carya ovata*	S4	+	
Rich Wet-Mesic Hardwood Forests	HARDWOOD TREES	*Celtis laevigata*	S5	+	
Rich Wet-Mesic Hardwood Forests	HARDWOOD TREES	*Juglans nigra*	S4	+	
Rich Wet-Mesic Hardwood Forests	HARDWOOD TREES	*Magnolia macrophylla*	S2		
Rich Wet-Mesic Hardwood Forests	HARDWOOD TREES	*Morus rubra*	S5	+	
Rich Wet-Mesic Hardwood Forests	HARDWOOD TREES	*Ulmus rubra*	S5		+