ECOLOGICAL AND FLORISTIC PLANT SURVEYS OF LITTLE WABASH RIVER NATURE PRESERVE, INDIANA

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ABSTRACT

Forests in northeastern Indiana are relegated to relatively small fragments and have become important patches in a landscape dominated by agriculture. Little Wabash River Nature Preserve is a property in Allen County, Indiana, closed to the public and protected by ACRES Land Trust. We conducted ecological surveys at 48 regular plots located along seven transects through the property that consisted of identifying and counting individual plants at understory, midstory, and overstory strata and recording several ecological factors. These were augmented by floristic meandering surveys during the growing season of 2019 to record plant species that may not have been encountered at the ecological plots and thereby give a fuller picture of the floristic composition of the property. We encountered a total of 251 identified species during the ecological and floristic surveys. Analysis showed understory abundance, richness, and diversity were positively related to available light (photosynthetically active radiation) and negatively related to canopy cover. The most abundant species in the midstory were non-native species. *Juglans nigra* had the greatest frequency and dominance in the overstory. In nonmetric multidimensional scaling, there was clear separation of the plant community within the forested portion from the community in the adjacent to the small old-field. Mean C-value for the site was 2.87, which resulted in a 41.56 FQI. The FQI may be an over-estimation of the conservation importance of the site and the Mean C-value may be an under-estimation of that importance. Overall, the Nature Preserve provides an example of the plant diversity can exist in a small, protected forest. While there are some common non-native species, there is habitat for a relatively large pool of species and may be of importance for protection within the surrounding disturbed landscape.

KEYWORDS: diversity, fragmentation, richness, nature preserve

INTRODUCTION

Most forests in northeastern Indiana are relatively small and isolated fragments of a formerly contiguous forest (Harman et al. 2019). Where forests do exist, they are often surrounded by artificial habitats, such as agricultural land or urban development. Edge effects on environmental gradients (e.g., light, moisture, temperature) and the limited size of core forest habitat results in changes in plant community structure and composition (Harman et al. 2019; Harper et al. 2005). These forest fragments provide essential landscape heterogeneity that provides habitat for arthropods, birds, and small mammals (Freemark and Merriam 1986; Myers and Marshall 2021; Nupp and Swihart 2000; Proesmans et al. 2019). The preservation of such isolated forest parcels has the potential to im-

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prove animal habitat and to protect rare plant communities (Rosenblatt et al. 1999; Fauth 2000; Diamond and Heinen 2016).

Floristic quality assessments (FQA) provide a systematic, repeatable approach to compare botanical communities within and between sites (Swink and Wilhelm 1994, Rothrock and Homoya 2005). Within FQA, there is a reliance on assigned C-values for each species encountered that facilitates the calculation of a floristic quality index (FQI) as an information statistic. While Swink and Wilhelm (1994) provided assigned C-values for species within the Chicago region, these values likely do not apply to locations outside of that region. For Indiana, C-values were subsequently assigned as only seven counties in Indiana are included in the Chicago region (Rothrock 2004, Rothrock and Homoya 2005). There are several criticisms of FQA, C-values, and FQI (Spyreas 2019), one of which is the subjectivity of assigned C-values. However, as an information statistic, there is aggregation of values within the calculation of Mean C-values and FQI, which will mitigate biases in certain species (Spyreas 2019). Additionally, there is inherent noise in the data related to differences in C-value lists and missing species from surveys (Rothrock and Homoya 2005). There are limitations to FQA and associated Mean C-value and FQI calculations, however, it is currently a usable tool for understanding community structure in relation to anthropogenic disturbance (Spyreas 2019, Werners et al. 2021).

Little Wabash River Nature Preserve (LWRNP) is a 14.3 ha property (of which approximately 13.0 ha is forested) within the Little River watershed that is located in Allen County in northeastern Indiana and is surrounded by agriculture, suburban development, and other forest fragments (Figure 1). LWRNP is situated in a geological valley feature created by the draining of Lake Maumee during the Wisconsin glaciation, known as the Maumee Megaflood (Fleming et al. 2018). Currently closed to the public, LWRNP is managed by ACRES Land Trust, which acquired the property in two units—the largest unit in 2004 (9.8 ha, all forested) and the smallest in 2015 (4.5 ha, 1.3 ha of which is an old field). In addition to ACRES Land Trust, LC Nature Park and Little River Wetlands Project are working to protect land within the Little River watershed. The objectives of this study were to characterize the plant community structure and composition at Little Wabash River Nature Preserve using systematic ecological surveys to associate community structure with environmental conditions and meandering floristic surveys to develop a comprehensive species list. Results from ecological and floristic surveys will be useful to ACRES Land Trust in making management decisions at the property and acquisition decisions in the region.

MATERIALS AND METHODS

Site Description

The property is mostly forested, but a 1.3 ha open field area does exist on the western side (Figure 1). LWRNP is dominated (72% of the area) by Glynwood clay loam soil (6–12% slope, moderately well drained). The southeastern portion of the property (24% of the area) is Eel silt loam soil (0–2% slope, frequently flooded). A small portion (4% of area) of LWRNP is Glynwood silt loam soil (2–6% slope, moderately well drained). Within the forested area, there is a 0.6 ha pond with open water.

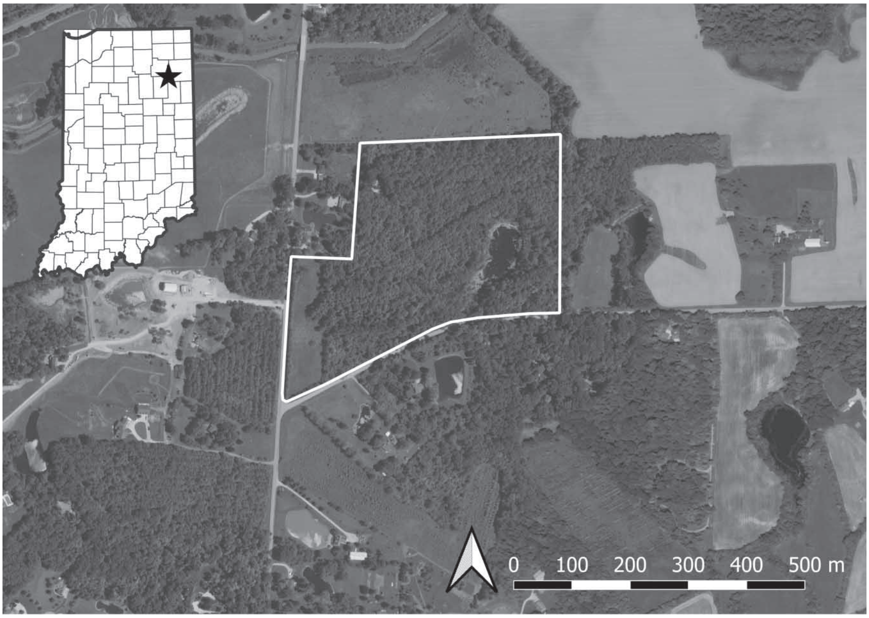

FIGURE 1. Little Wabash River Nature Preserve location and aerial image. Property boundary outlined in white. Aerial image is from the National Agricultural Imagery Program (USDA Farm Service Agency Aerial Photography Field Office).

Ecological Surveys

Understory Surveys and Environmental Conditions

Understory plants were surveyed and ecological data recorded during three seasonal periods: May 13–18, July 13–21, and September 20–21 2019. To link plant community data to environmental conditions, we established seven transects, spaced 50 m apart, running southeast to northwest within LWRNP. Along each transect we established 1 m^2 quadrats spaced 30 m apart; there were a total of 48 quadrats. As the transects were not of equal length, the number of quadrats per transect were not equal. We surveyed all quadrats during the May, July, and September surveys. Within each 1 m^2 quadrat, we identified to species and counted individuals of all plants ≤ 2 m in height rooted in the quadrat. Species nomenclature throughout all surveys follows the Integrated Taxonomic Information System (ITIS, 2023). Voucher specimens were collected when species were encountered for the first time, whenever possible (i.e., we considered the population to be large enough and the species common enough), and deposited in the Purdue University Fort Wayne Department of Biological Sciences herbarium.

At the center of each quadrat, we measured photosynthetically active radiation (PAR) (µmol/m^2/sec) 1 m above the soil surface with a six-sensor linear ceptometer (Spectrum Technologies, Aurora, Illinois), the percentage of volumetric soil moisture content with a time domain reflectometer with 12 cm sensor rods (Spectrum Technologies, Aurora, Illinois), litter depth (cm) with a meterstick, and the percentage of canopy cover with a spherical concave densiometer (Forestry Suppliers, Jackson, MS) using standard protocols (Lemon 1956). PAR light data was converted to percentage of available PAR by dividing the quadrat data by an unattended light sensor continuously logging 100% solar radiation in an open, unshaded portion of the property.

Midstory and Overstory Survey

Midstory plant surveys were conducted on August 10–11, 2019 within 25 m^2 (5 m × 5 m) plots centered on each understory quadrat. All plants > 2 m in height and < 8 cm diameter at breast height

(DBH, 1.37 m above the soil surface) were identified to species and stems were counted for each species.

Overstory plant surveys were conducted on August 10–11, 2019 within 500 m^2 circular plots (12.62 m radius) centered on each understory quadrat. All trees ($\geq$ 8 cm in DBH) were identified to species and basal area (m^2/ha) was determined from 10-factor prism counts for each species. While not identified to species, we also counted standing dead trees. The relative dominance of each species was calculated as the basal area of the species, divided by the sum of the basal areas of all species multiplied by 100. The relative frequency of each species was calculated as the frequency of the species (the number of plots in which the species occurs divided by the total number of plots surveyed) divided by the sum of the frequencies of all species multiplied by 100. The relative density of each species was calculated as the number of individuals of the species divided by the total number of individuals of all species multiplied by 100. The importance values of each species were then calculated as the sum of the relative dominance, the relative frequency, and the relative density of that species, divided by three.

Floristic Surveys

The floristic surveys were conducted between April and October 2019 (18 visits, every 1-3 weeks during survey period, some visits in the same week) to ensure that all habitat areas within LWRNP were visited and that plant species not encountered during the ecological surveys would be cataloged. As the survey transects were spaced 50 m apart, there were clearly areas of the property that were not surveyed. The floristic surveys turned up additional species that were not encountered during the ecological surveys. Due to the stochastic nature of the floristic surveys, the location and environmental conditions were not recorded. However, voucher specimens were collected of species encountered for the first time, whenever possible, and deposited in the Purdue University Fort Wayne herbarium.

Analysis

Floristic Quality Assessment

For all species encountered in the ecological and floristic understory surveys, we used the coefficient of conservatism (C or C-value) assigned by Rothrock (2004) for Indiana for subsequent calculations. These C-values range from 0 to 10 with lower values associated with species that can tolerate disturbance and greater C-values associated with species that cannot tolerate disturbance. A floristics quality index (FQI) was calculated for the site based on C-values and provided a relative comparison value of the conservation importance as a remnant habitat. FQI was calculated as

$$\text{FQI} = \text{Mean C-value} \sqrt{N}$$

where Mean C-value was the calculated mean value for all species C-values at LWRNP and N is the total of native species present in the site. We used Method 2 as described by Rothrock (2004) where non-native species have a C-value of zero.

Statistical Analysis

Species richness (the number of species present) was recorded and the species diversity, using Shannon's index, was calculated for each understory quadrat and each midstory and overstory plot based on abundance (count of individuals). Shannon's index is an information statistic used as a measure of entropy within an ecological community and of uncertainty (Hayek and Buzas 1997). We calculated Shannon's index following Hayek and Buzas (1997) as

$$\text{Shannon's index} = -\sum p_i \log p_i$$

where p_i is the proportion of the ith species ($p_i = n_i/N$, where n_i is the abundance of the ith species and N is the total abundance). Total understory abundance (counts of all individuals), richness, and diversity were analyzed using mixed effect linear regression with each of the following environmental factors: percentage of available PAR, percentage of soil moisture, litter depth, and canopy cover as independent fixed factors and with survey month as a random effect. A Wald chi-square test was used to test the confidence in the influence of the fixed effects on the dependent variable. Nonmetric multidimensional scaling (NMDS) ordination was used to visualize understory plant community composition at LWRNP based on species stem counts using the metaMDS function in the *vegan* package with default options (Oksanen et al. 2022). Bray-Curtis dissimilarity was used as the distance measure within the NMDS ordination. Through the 'autotransform=TRUE' option, the data was transformed using a Wisconsin double standardization with square root function. Joint vectors were displayed to represent influence of environmental variables on the plot locations in species space. Environmental variables were midstory species richness and diversity, overstory species richness and diversity, overstory dead tree basal area, percentage of canopy cover, percentage of soil moisture, percentage of PAR, and litter depth. We used an $R^2 = 0.2$ as an arbitrary threshold, omitting joint vectors from the NMDS plot that were below the threshold. Unweighted average linkage hierarchical clustering was used to identify separation in clusters within the NMDS plot. All analyses were conducted in R version 4.2.2 (R Core Team 2022).

RESULTS

Ecological Surveys

Understory Survey

We encountered 118 understory species in 47 families (Table 1). Three quadrats had zero individuals and they were different locations during the survey period (one in May, two in September). Thirty-eight of the species occurred in only a single quadrat. Forty-one species occurred on only one sampling date, thirty on two dates, and forty-seven occurred on all three sampling dates.

With month as a random effect, understory abundance ($X^2 = 38.18$, $p < 0.001$), richness ($X^2 = 43.63$, $p < 0.001$), and diversity ($X^2 = 14.64$, $p < 0.001$) were positively related to the percentage of available PAR (Figure 2). Similarly, abundance ($X^2 = 14.37$, $p < 0.001$) was positively related to the percentage of soil moisture, however, richness and diversity were not related to soil moisture ($X^2 = 2.68$, $p = 0.102$; $X^2 = 0.05$, $p = 0.821$; respectively; Figure 2). Litter depth did not have a significant influence on abundance ($X^2 = 1.48$, $p = 0.223$), richness ($X^2 = 2.68$, $p = 0.102$), or diversity ($X^2 = 3.26$, $p = 0.071$) (Figure 2). As would be expected, canopy cover had an inverse influence on abundance ($X^2 = 145.16$, $p < 0.001$), richness ($X^2 = 107.13$, $p < 0.001$), and diversity ($X^2 = 27.13$, $p < 0.001$) compared to available PAR (Figure 2).

NMDS ordination was used to visualize the understory plant community at LWRNP (Figure 3). A small cluster of eleven plots were separate from the other plots within the NMDS. These included plots that occurred in the old field on the western side of LWRNP and along the transects adjacent to the old field. The separation of this cluster in the NMDS was positively influenced by soil moisture and available PAR in those plots. Conversely, this cluster was negatively influenced by canopy cover, overstory richness, and overstory diversity (Figure 3).

Midstory Survey

We encountered 23 midstory species in 12 families (Table 2). Nine plots contained no midstory individuals. The non-native *Lonicera maackii* (Ruper.) Herder was by far the most frequently occurring (i.e., occurred in the greatest number of plots) and most abundant (i.e., with the greatest number of individuals per plot) midstory species encountered (Table 2). Other non-native species

TABLE 1. Species encountered during the understory ecological surveys, the number of quadrats in which each occurred, and the mean number of individuals per quadrat (standard error in parentheses).

Family	Scientific name	Plots	Count
Adoxaceae	*Sambucus canadensis* L.	1	3.0
Anacardiaceae	*Toxicodendron radicans* (L.) Kuntze	16	7.3 (2.5)
Apiaceae	*Cryptotaenia canadensis* (L.) DC.	1	9.0
Apiaceae	*Daucus carota* L.	11	32.0 (7.7)
Apiaceae	*Erigenia bulbosa* (Michx.) Nutt.	1	7.0
Apiaceae	*Osmorhiza claytonii* (Michx.) C.B. Clarke	9	7.1 (1.8)
Apiaceae	*Pastinaca sativa* L.	3	3.3 (1.9)
Apiaceae	*Sanicula canadensis L.*	10	25.8 (8.5)
Apocynaceae	*Apocynum cannabinum* L.	5	8.0 (4.3)
Apocynaceae	*Asclepias syriaca* L.	2	2.0 (0.0)
Asparagaceae	*Convallaria majalis* L.	1	330.0
Asparagaceae	*Maianthemum racemosum* (L.) Link	1	1.0
Asparagaceae	*Polygonatum biflorum* (Walter) Elliott	2	2.0 (0.7)
Aspleniaceae	*Asplenium platyneuron* (L.) Britton, Sterns & Poggenb.	1	3.0
Asteraceae	*Ageratina altissima* (L.) R.M. King & H. Rob	7	11.0 (2.6)
Asteraceae	*Ambrosia artemisiifolia* L.	4	3.0 (0.8)
Asteraceae	*Arctium minus* (Hill) Bernh.	2	2.5 (1.1)
Asteraceae	*Cirsium arvense* (L.) Scop.	2	1.0 (0.0)
Asteraceae	*Erigeron annuus* (L.) Pers.	7	13.4 (6.1)
Asteraceae	*Euthamia graminifolia* (L.) Nutt.	1	2.0
Asteraceae	*Leucanthemum vulgare* Lam.	9	2.8 (0.6)
Asteraceae	*Packera glabella* (Poir) C. Jeffrey	1	1.0
Asteraceae	*Solidago altissima* L.	5	9.0 (2.2)
Asteraceae	*Solidago canadensis* L. var. *hargeri* Fernald	8	28.1 (9.3)
Asteraceae	*Solidago* sp. L.	4	17.5 (8.3)
Asteraceae	*Symphyotrichum lanceolatum* (Willd.) G.L. Nesom	9	20.1 (6.4)
Asteraceae	*Symphyotrichum shortii* (Lindl.) G.L. Nesom	1	5.0
Asteraceae	*Taraxacum officinale* F.H. Wigg.	7	3.4 (1.1)
Asteraceae	*Vernonia gigantea* (Walter) Trel.	2	7.0 (4.2)
Balsaminaceae	*Impatiens capensis* Meerb.	7	10.6 (2.8)
Brassiaceae	*Cardamine douglassii* Britton	1	1.0
Brassicaceae	*Alliaria petiolata* (M. Bieb.) Cavara & Grande	13	16.6 (5.3)
Brassicaceae	*Cardamine concatenata* (Michx.) Sw.	2	8.0 (2.8)
Brassicaceae	*Lepidium campestre* (L.) W.T. Aiton	2	9.5 (1.8)
Cannabaceae	*Celtis occidentalis* L.	10	1.8 (0.3)
Caprifoliaceae	*Lonicera maackii* (Rupr.) Herder	21	5.5 (1.2)
Caryophyllaceae	*Cerastium fontanum* Baumg.	1	4.0
Caryophyllaceae	*Stellaria media* (L.) Vill.	1	4.0
Celastraceae	*Euonymus atropurpureus* Jacq.	2	1.5 (0.4)
Cornaceae	*Cornus drummondii* C.A. Mey	3	2.0 (0.5)
Cornaceae	*Cornus racemosa* Lam.	3	2.0 (0.5)
Cyperaceae	*Carex granularis* Muhl. ex Willd.	1	1.0
Cyperaceae	*Carex jamesii* Schwein.	13	7.5 (2.4)
Cyperaceae	*Carex normalis* Mack.	1	2.0
Cyperaceae	*Carex stipata* Muhl. ex Willd.	7	6.7 (2.2)
Cyperaceae	*Carex vulpinoidea* Michx.	1	7.0
Cyperaceae	*Scirpus atrovirens* Willd.	1	1.0
Elaeagnaceae	*Elaeagnus umbellata* Thunb.	8	6.0 (1.6)
Fabaceae	*Cercis canadensis* L.	3	9.3 (4.8)
Fabaceae	*Medicago sativa* L.	1	1.0
Fabaceae	*Trifolium pratense* L.	9	12.7 (3.4)

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TABLE 1. (*Continued*).

Family	Scientific name	Plots	Count
Fabaceae	*Trifolium repens* L.	5	9.4 (2.3)
Fagaceae	*Quercus alba* L.	1	2.0
Fagaceae	*Quercus bicolor* Willd.	1	4.0
Fagaceae	*Quercus rubra* L.	2	1.0 (0.0)
Geraniaceae	*Geranium maculatum* L.	1	28.0
Grossulariaceae	*Ribes cynosbati* L.	2	1.0 (0.0)
Hydrophyllaceae	*Hydrophyllum appendiculatum* Michx.	1	1.0
Hydrophyllaceae	*Hydrophyllum macrophyllum* Nutt.	1	2.0
Juglandaceae	*Carya cordiformis* (Wangenh.) K. Koch	2	3.0 (0.0)
Juncaceae	*Juncus tenuis* Willd.	4	4.5 (1.3)
Lamiaceae	*Blephilia hirsuta* (Pursh) Benth.	4	3.8 (1.1)
Lamiaceae	*Glechoma hederacea* L.	3	3.0 (0.9)
Lamiaceae	*Prunella vulgaris* L.	3	8.3 (2.6)
Liliaceae	*Erythronium americanum* Ker Gawl.	3	12.7 (2.6)
Limnanthaceae	*Floerkea proserpinacoides* Willd.	6	13.0 (3.4)
Menispermaceae	*Menispermum canadense* L.	1	8.0
Montiaceae	*Claytonia virginica* L.	1	4.0
Oleaceae	*Fraxinus pennsylvanica* Marshall	27	15.9 (5.0)
Oleaceae	*Fraxinus quadrangulata* Michx.	2	12.5 (5.3)
Onagraceae	*Circaea lutetina* L. ssp. *canadensis* (L.) Asch. & Magnus	14	12.2 (3.0)
Oxalidaceae	*Oxalis dillenii* Jacq.	7	5.7 (2.2)
Phrymaceae	*Phryma leptostachya* L.	1	1.0
Pinaceae	*Pinus strobus* L.	1	3.0
Plantaginaceae	*Plantago lanceolata* L.	10	36.9 (8.5)
Plantaginaceae	*Plantago rugelii* Decne.	3	1.7 (0.3)
Poaceae	*Agrostis gigantea* Roth	9	38.8 (6.8)
Poaceae	*Bromus pubescens* Muhl. ex Willd.	1	2.0
Poaceae	*Dactylis glomerata* L.	2	10.0 (0.0)
Poaceae	*Dichanthelium boscii* (Poir.) Gould & C.A. Clark	5	2.4 (0.7)
Poaceae	*Dichanthelium linearifolium* (Scribn. ex Nash) Gould	7	9.3 (1.8)
Poaceae	*Elymus hystrix* L.	1	7.0
Poaceae	*Glyceria striata* (Lam.) Hitchc.	14	30.3 (5.9)
Poaceae	*Phleum pratense* L.	8	107.1 (22.1)
Poaceae	*Poa pratensis* L. ssp. *pratensis*	2	22.5 (0.4)
Poaceae	*Poa sylvestris* A. Gray	3	15.3 (10.1)
Polygonaceae	*Persicaria virginiana* (L.) Gaertn	22	29.3 (5.4)
Ranunculaceae	*Actaea pachypoda* Elliott	1	10.0
Ranunculaceae	*Anemone canadensis* L.	1	4.0
Ranunculaceae	*Ranunculus abortivus* L.	1	2.0
Ranunculaceae	*Ranunculus recurvatus* Poir.	5	2.2 (0.7)
Rosaceae	*Duchesnea indica* (Andrews) Focke var. *indica*	2	6.5 (3.2)
Rosaceae	*Fragaria vesca* L.	5	6.0 (1.9)
Rosaceae	*Fragaria vesca* L. subps. *vesca*	3	1.7 (0.5)
Rosaceae	*Geum canadense* Jacq.	16	7.5 (1.3)
Rosaceae	*Geum* sp. L.	8	11.6 (4.0)
Rosaceae	*Geum vernum* (Raf.) Torr. & A. Gray	13	2.5 (0.3)
Rosaceae	*Prunus serotina* Ehrh.	6	1.5 (0.2)
Rosaceae	*Rosa multiflora* Thunb.	7	5.9 (1.6)
Rosaceae	*Rubus occidentalis* L.	6	5.7 (1.3)
Rubiaceae	*Galium aparine* L.	18	5.4 (0.9)
Rubiaceae	*Galium asprellum* Michx.	1	1.0
Rubiaceae	*Galium circaezans* Michx.	1	1.0
Rubiaceae	*Galium concinnum* Torr. & A. Gray	2	6.5 (3.2)

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TABLE 1. (*Continued*).

Family	Scientific name	Plots	Count
Rubiaceae	*Galium triflorum* Michx.	7	3.1 (0.8)
Sapindaceae	*Acer saccharum* Marshall	6	2.3 (1.0)
Sapindaceae	*Aesculus glabra* Willd.	1	2.0
Smilaceae	*Smilax* sp. L.	1	2.0
Smilaceae	*Smilax tamnoides* L.	1	2.0
Solanaceae	*Solanum carolinense* L.	3	1.7 (0.5)
Ulmaceae	*Ulmus americana* L.	10	2.5 (0.7)
Urticaceae	*Boehmeria cylindrica* (L.) Sw.	1	1.0
Urticaceae	*Laportea canadensis* (L.) Benth.	1	37.0
Urticaceae	*Pilea pumila* (L.) A. Gray	7	16.0 (7.0)
Violaceae	*Viola sororia* Willd.	8	32.1 (6.6)
Violaceae	*Viola striata* Aiton	3	18.0 (13.1)
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	29	14.3 (2.4)
Vitaceae	*Vitis vulpina* L.	8	1.5 (0.3)

were observed in the midstory plots (*Lonicera tatarica* L., *Elaeagnus umbellata* Thunb., and *Rosa multiflora* Thunb.), but they were much less common than *L. maackii*. *Fraxinus pennsylvanica* Marshall was the most frequent native species (Table 2).

Overstory Survey

We encountered 32 overstory species in 16 families (Table 3). Eleven plots had no overstory individuals within the 500 m^2 circular boundary. *Juglans nigra* L. was the most frequently occurring and most dominant species, resulting in being the top-ranked species by importance value (Table 3). The spatial arrangement of *J. nigra* we observed in the forest (not quantified) suggests it was planted by previous land owners and may not represent natural recruitment of the species—regular spacing, stems of equal size. Standing dead trees, which we treated as a single species, had the third highest importance value, outranking *Acer saccharum* Marshall due to frequency (Table 3).

Floristic Surveys

We conducted floristic surveys 18 times during the survey period, none of which individually covered the entire property. During the floristic surveys, we encountered an additional 137 species unique to the floristic survey – we did encounter 99 species shared with the ecological surveys (see Appendix 1). Several of the species found only during the floristic survey were of note, including eight species of Cyperaceae (sedges), two of Ophioglossaceae (adder's-tongue ferns), and three of Orchidaceae (orchids). While these were not necessarily rare, the were found because of the numerous visits with the floristic survey.

There were six species we could only identify to genus (Appendix 1). In each case, the individuals encountered were lacking key diagnostic characteristics and we were unable to confidently identify the species. It is possible that these specimens were actually the same as other species identified in the genera. Omitting

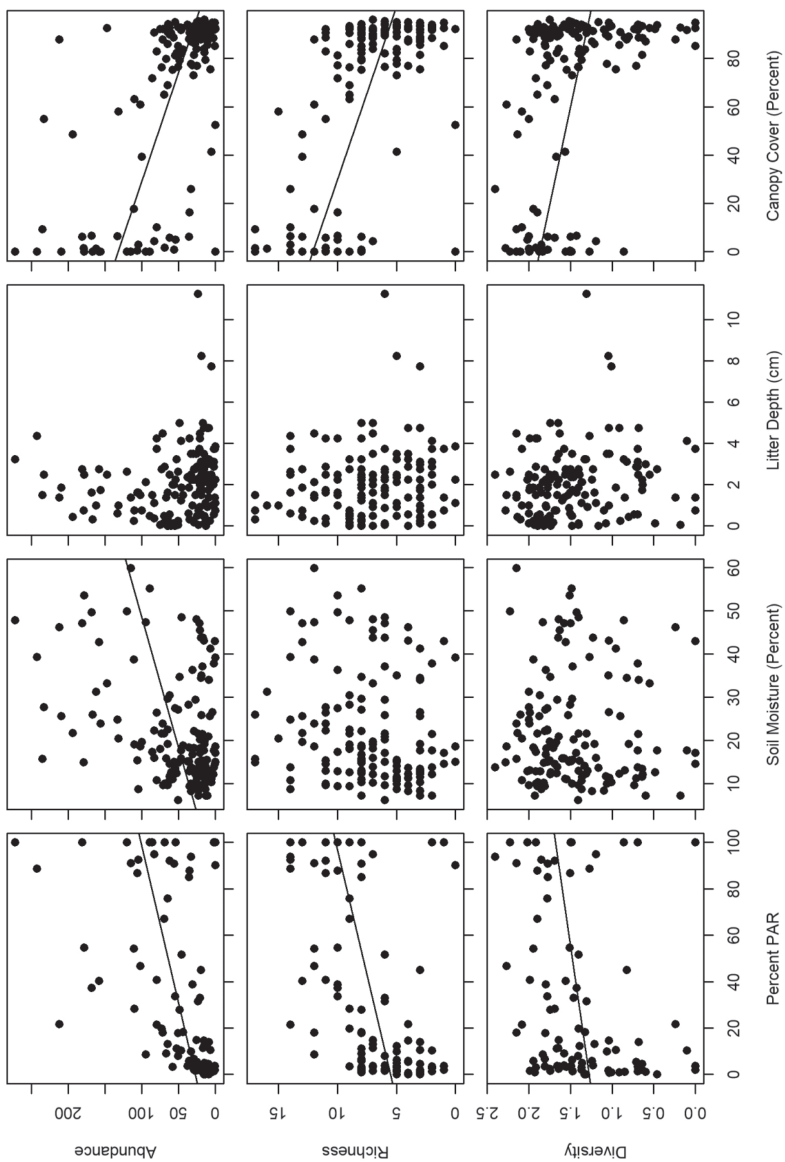

FIGURE 2. The relationships between understory abundance, richness, and diversity and environmental variables (the percentage of available photosynthetically active radiation [PAR], the percentage of volumetric soil moisture content, litter depth, and the percentage of canopy cover). Only significant relationships are represented by a line. The regression analysis included the survey month as a random effect.

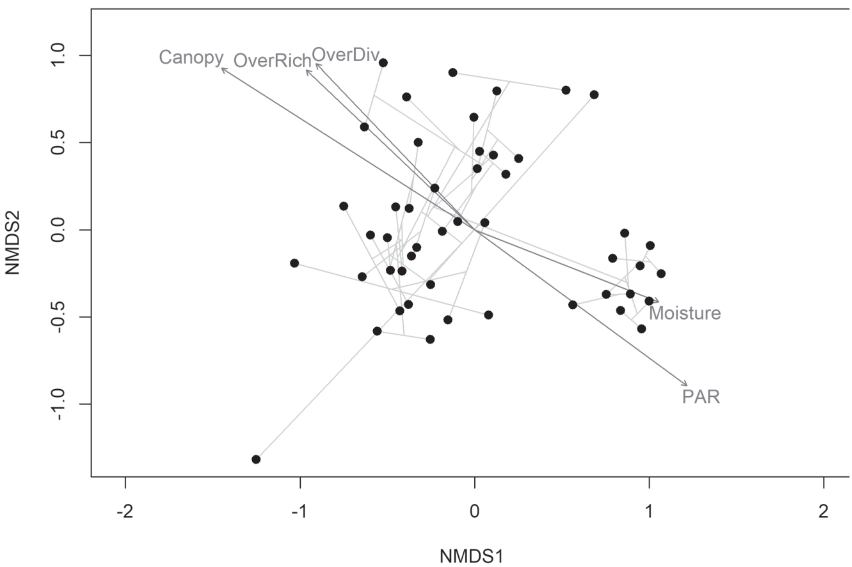

FIGURE 3. Nonmetric multidimensional scaling (NMDS) ordination of understory species based on stem counts within Little Wabash River Nature Preserve. Joint vectors represent relationships with environmental variables with an $R^2 > 0.2$; Canopy is percentage of overstory canopy cover, Moisture is the volumetric percentage of soil moisture content, PAR is the percentage of available photosynthetically active radiation, OverRich is overstory species richness, and OverDiv is the Shannon diversity index of overstory species. The light gray lines connecting points represent unweighted average linkage hierarchical clustering.

these six species only identified to genus, we encountered 251 species in the three strata (Appendix 1).

Only two species encountered at LWRNP had high C-values (i.e., intolerant of disturbance) –*Spiranthes magnicamporum* Sheviak (found in a subsequent visit in 2022) and *Taxodium distichum* (L.) Rich. var. *distichum* (Cupressaceae). Most species had a C-value of 6 or less (93.3% of those with assigned C-values). Approximately 17.3% of species did not have an assigned C-value due to being non-native species. The mean C-value for LWRNP was 2.89; based on 209 native species, LWRNP had an FQI of 41.56.

DISCUSSION

As most forests in northeast Indiana are relegated to disjunct fragments of a once-continuous forest, all well-established closed canopy forests represent important habitat for plants and animals in the region (Harman et al. 2019). Although LWRNP has a relatively open canopy (mean canopy cover = 71.5% across sampling dates in July and September), it is still an important part of the forest matrix in the region, and although it has clear evidence of past human ma-

TABLE 2. Species encountered in the midstory ecological surveys, the number of plots in which each occurred, and the mean number of individuals per plot (standard error in parentheses).

Family	Species name	Plots	Count
Adoxaceae	*Sambucus canadensis* L.	2	3.0 (2.0)
Cannabaceae	*Celtis occidentalis* L.	8	1.8 (0.4)
Caprifoliaceae	*Lonicera maackii* (Ruper.) Herder	30	11.6 (1.4)
Caprifoliaceae	*Lonicera tatarica* L.	3	5.0 (1.9)
Cornaceae	*Cornus drummondii* C.A. Mey.	10	3.9 (1.2)
Cornaceae	*Cornus racemosa* Lam.	6	3.3 (0.9)
Elaeagnaceae	*Elaeagnus umbellata* Thunb.	10	3.3 (1.0)
Fagaceae	*Quercus bicolor* Willd.	5	1.2 (0.2)
Fagaceae	*Quercus coccinea* Münchh.	1	1.0
Fagaceae	*Quercus rubra* L.	2	1.0
Juglandaceae	*Carya cordiformis* (Wangenh.) K. Koch	5	1.2 (0.2)
Juglandaceae	*Carya ovata* (Mill.) K. Koch	3	1.0
Juglandaceae	*Juglans nigra* L.	4	1.0
Oleaceae	*Fraxinus pennsylvanica* Marshall	18	4.4 (0.6)
Oleaceae	*Fraxinus quadrangulata* Michx.	3	3.7 (1.2)
Rosaceae	*Crataegus* sp. L.	1	7.0
Rosaceae	*Prunus serotina* Ehrh.	1	1.0
Rosaceae	*Prunus virginiana* L.	1	8.0
Rosaceae	*Rosa multiflora* Thunb.	1	2.0
Sapindaceae	*Aesculus glabra* Willd.	2	1.5 (0.4)
Sapindaceae	*Acer saccharum* Marshall	4	1.5 (0.4)
Ulmaceae	*Ulmus americana* L.	1	1.0
Ulmaceae	*Ulmus rubra* Muhl.	1	2.0

nipulation—e.g., winter aerial images display clear fence-line plantings of conifers, observed plantation patterns of *Juglans nigra*, occurrences of *Taxodium distichum* in the understory and overstory well beyond the northern range in the Midwest (Wilhite and Toliver 1990)—species of interest were nevertheless encountered.

We found three orchid species (Orchidaceae), two of which, *Liparis liliifolia* (L.) Rich. ex Ker Gawl. and *Spiranthes lacera* (Raf.) Raf. var. *gracilis* (Bigelow) Luer, have limited occurrence records in northeastern Indiana. These two orchid species, in addition to *Spiranthes cernua* (L.) Rich., have relatively low C-value (3), which indicates species that provide little or no confidence that its habitat signifies remnant conditions (Rothrock 2004). This suggests that they are adapted to habitats that are at least somewhat disturbed. Since they were found in a relatively disturbed portion of the property, management in that area to reduce overstory and midstory canopy, as well as to provide regular disturbance, will likely promote success in *L. liliifolia* and *S. lacera* var. *gracilis*, especially since closed canopy mature forest is not suitable habitat for these species (Morris 1989, Mattrick 2004). *Spiranthes magnicamporum* and *Spiranthes ovalis,* were observed during a subsequent site visit in 2022 as we were confirming the identification of *S. cernua*. We included *S. magnicamporum* and *S. ovalis* in Appendix 1 with the indication that they were observed outside of our original floristic survey dates.

Spiranthes magnicamporum (added in the subsequent visit in 2022) and *Tax-*

TABLE 3. Species encountered during the overstory ecological surveys and the frequency (number of plots), density (mean number of stems per plot) (standard error in parentheses), dominance (basal area in m^2/ha), and importance value (IV) of each.

Family	Species name	Frequency	Density	Dominance	IV
Altingaceae	*Liquidambar styraciflua* L.	5	2.7 (0.8)	0.70	3.43
Betulaceae	*Betula papyrifera* Marshall	1	1.0	0.05	0.76
Betulaceae	*Carpinus caroliniana* Walter	1	1.0	0.05	0.76
Betulaceae	*Ostrya virginiana* (Mill.) K. Koch	1	1.0	0.05	0.76
Cannabaceae	*Celtis occidentalis* L.	6	1.2 (0.3)	0.37	2.44
Cornaceae	*Cornus drummondii* C.A. Mey.	2	1.0	0.10	1.06
Cornaceae	*Cornus racemosa* Lam.	3	2.7 (1.4)	0.42	2.56
Cupressaceae	*Juniperus virginiana* L.	5	5.8 (2.2)	1.51	6.12
Cupressaceae	*Taxodium distichum* (L.) Rich.	1	4.0	0.21	2.39
Ebenaceae	*Diospyros virginiana* L.	1	3.0	0.16	1.85
Fagaceae	*Quercus alba* L.	1	1.0	0.05	0.76
Fagaceae	*Quercus bicolor* Willd.	15	4.3 (0.6)	3.34	10.46
Fagaceae	*Quercus coccinea* Münchh.	1	1.0	0.05	0.76
Fagaceae	*Quercus muehlenbergii* Engelm.	2	1.0	0.10	1.06
Fagaceae	*Quercus rubra* L.	10	1.6 (0.3)	0.83	4.22
Juglandaceae	*Carya cordiformis* (Wangenh.) K. Koch	4	2.9 (0.9)	0.60	3.15
Juglandaceae	*Carya ovata* (Mill.) K. Koch	6	1.4 (0.3)	0.44	2.65
Juglandaceae	*Juglans nigra* L.	20	4.0 (0.7)	4.20	12.76
Magnoliaceae	*Liriodendron tulipifera* L.	4	1.9 (0.9)	0.39	2.36
Oleaceae	*Fraxinus pennsylvanica* Marshall	7	1.3 (0.2)	0.47	2.87
Oleaceae	*Fraxinus quadrangulata* Michx.	2	2.0	0.21	1.69
Pinaceae	*Picea glauca* (Moench) Voss	1	3.0	0.16	1.85
Pinaceae	*Pinus strobus* L.	2	1.5 (0.4)	0.16	1.38
Rosaceae	*Crataegus* sp. L.	1	3.0	0.16	1.85
Rosaceae	*Prunus serotina* Ehrh.	10	3.6 (1.1)	1.85	6.73
Salicaeae	*Populus deltoides* W. Bartram ex Marshall	2	3.0 (0.7)	0.31	2.30
Sapindaceae	*Acer negundo* L.	1	1.0	0.05	0.76
Sapindaceae	*Acer saccharinum* L.	1	1.0	0.05	0.76
Sapindaceae	*Acer saccharum* Marshall	10	3.6 (0.8)	1.85	6.73
Sapindaceae	*Aesculus glabra* Willd.	1	2.0	0.10	1.30
Ulmaceae	*Ulmus americana* L.	7	1.9 (0.5)	0.70	3.50
Ulmaceae	*Ulmus rubra* Muhl.	1	1.0	0.05	0.76
	Dead trees	17	1.9 (0.3)	1.70	7.25

odium distichum were the only two species encountered at LWRNP that had a C-value of 10, the latter of which, as noted above, is outside its natural range at LWRNP. Only 6.7% of the species encountered in the ecological and floristic surveys had a C-value > 6; C-values of 6 and below are associated with species able to tolerate significant or moderate disturbance (Rothrock 2004). Wilhelm et al. (2003) suggested that habitats with Mean C-values of 2 or less are typically old fields and highly degraded sites. Additionally, habitats with Mean C-values of 5 or more would be sites characteristic of a pre-European settlement plant community (Rothrock 2004). The Mean C-value at LWRNP was 2.87, which further supports our interpretation that human influence has played a significant role at the site. This low Mean C-value suggests that there has been significant disturbance to the site, although it may not be fully degraded. FQI values are collinear with species richness (i.e., FQI values align with species richness and are influenced by similar environmental factors), and Rooney and Rogers (2002) suggested using Mean C-value as a modified FQI value, which may be less influenced by the same environmental factors as species richness. Our FQI value at LWRNP (41.56) would suggest it is an exceptional site floristically, even with the extensive human influence of disturbance. This FQI value may be an overestimate of the floristic quality, however, the Mean C-value (2.87) may be an under-estimate of the floristic quality. By comparison, Fogwell Forest Nature Preserve (same county, 6.5 km away) has a Mean C-value of 3.60 and an FQI of 55.4, which has a plant community indicative of limited disturbance (Rothrock and Homoya 2005, Arvola et al. 2014). Rothrock (1997) noted the absence of non-native species were limited to the ecotone and old field and not in the core of the forest.

Even more evidence of the human influence at LWRNP was found in the midstory. Although there were only four non-native species in the midstory, they made up 65% of the total number of midstory individuals. The remaining 45% of midstory individuals belonged to 19 native species. The non-native *Lonicera maackii* accounted for 56% of all midstory individuals.

Long-term human impact on the plant community is evident in the overstory. Some of the overstory species with the five highest importance values were expected, while others were not. The overstory species with the highest importance value was *Juglans nigra*, which does not commonly dominate forests in northeastern Indiana, and Eyre (1980) does not define a Black Walnut forest type. The economic value of *J. nigra* likely led to the mass planting of this species by previous owners because it is currently among the highest values for sawlogs in Indiana (Settle and Gonso 2019). The species with the second and fourth highest importance values (*Quercus bicolor* Willd. and *Prunus serotina* Ehrh.) are known associates of *J. nigra* (Williams 1990). Standing dead trees had the third highest importance value in the overstory survey. These are essential in providing wildlife roosting sites and may provide insight into the relatively low percentage of canopy cover. *Acer saccharum* L., which shared the fourth highest importance value with *P. serotina*, is commonly the dominant species in second-growth forests in northeastern Indiana (e.g., Arvola et al. 2014, Bisht et al. 2017, Harman et al. 2019), which is why its lower rank at LWRNP was surprising.

Overall, LWRNP provides habitat to a relatively large pool of plant species (251 species across the three strata). Due to fragmentation, isolation, and diminished size of forests in the region, this property is of importance to preserving species and habitat. LWRNP provides an example of the plant diversity can exist in a small, protected forest. While the forest has been manipulated and its community structure dominated by human influence, there is still conservation value in continued protection of this site.

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LITERATURE CITED

Arvola, K. D., P. F. Booth, C. C. Ellinwood, A. J. Fry, J. L. Furge, K. A. Haehnle, L. E. Hall, et al. (2014). Comparative analysis of urban and rural forest fragment structure and diversity in Northeastern Indiana. The Michigan Botanist 53: 39–59.

Bisht, A., K. L. Fracica, A. M. Gutierrez, J. R. Hinson, A. A. Hopkins, J. M. Josimovich, M. N. Matthews, et al. (2017). Survey of Haskamp Woods, Allen County, Indiana, and floristic comparison with neighboring forest properties. Phytoneuron 2017-69: 1–13.

Diamond, J. M., and J. T. Heinen. (2016). Conserving rare plants in locally-protected urban forest fragments: A case study from Miami-Dade County, Florida. Urban Forestry & Urban Greening 20: 1–11.

Eyre, F. H. (1980). Forest cover types of the United States and Canada. Society of American Foresters, Washington, D.C.

Fauth, P. T. (2000). Reproductive success of wood thrushes in forest fragments in northern Indiana. The Auk 117: 194–204.

Fleming, A. H., J. O. Farlow, A. Argast, G. M. Grammer, and D. Prezbindowski. (2018). The Maumee Megaflood and the geomorphology, environmental geology, and Silurian-Holocene history of the upper Wabash Valley and vicinity, north-central Indiana. Pp. 259-337 in Ancient oceans, orogenic uplifts, and glacial ice: Geologic crossroads in America's heartland. L. J. Florea, editor. Geological Society of America, Boulder, Colorado.

Freemark, K. E., and H. G. Merriam. (1986). Importance of area and habitat heterogeneity to bird assemblages in temperate forest fragments. Biological Conservation 36: 115–141.

Harman, R. R., A. R. De Leon, H. M. Lancaster, and J. M. Marshall. (2019). Relative influence of spatial and structural characteristics of forest fragments on woody plant communities. The Great Lakes Botanist 58: 32–56.

Harper, K. A., S. E. MacDonald, P. J. Burton, J. Chen, K. D. Brosofske, S. C. Saunders, E. S. Euskirchen, et al. (2005). Edge influence on forest structure and composition in fragmented landscapes. Conservation Biology 19: 768–782.

Hayek, L. C., and M. A. Buzas. (1997). Surveying natural populations. Columbia University Press, New York, N.Y.

ITIS. (2023). Integrated Taxonomic Information System. Available at https://www.itis.gov (Accessed July 31, 2023).

Lemon, P. E. (1956). A spherical densiometer for estimating forest overstory density. Forest Science 2: 314–320.

Mattrick, C. (2004). *Liparis liliifolia* (L.) L. C. Rich. ex Lindley, Lily-leaved twayblade: Conservation and research plan for New England. New England Plant Conservation Program, New England Wild Flower Society. Available at https://www.nativeplanttrust.org/documents/75/Liparis_liliifolia.pdf (Accessed October 10, 2022).

Morris, M. W. (1989). *Spiranthes* (Orchidaceae) in Mississippi. Selbyana 11: 39–48.

Myers, A. L., and J. M. Marshall. (2021). Influence of forest fragment composition and structure on ground-dwelling arthropod communities. The American Midland Naturalist 186: 76–94.

Nupp, T. E., and R. K. Swihart. (2000). Landscape-level correlates of small-mammal assemblages in forest fragments of farmland. Journal of Mammalogy 81: 512–526.

Oksanen, J., G. Simpson, F. Blanchet, R. Kindt, P. Legendre, P. Minchin, R. O'Hara, et al. (2022). vegan: Community ecology package. R package version 2.6-2. Available at https://CRAN.R-project.org/package=vegan (Accessed July 31, 2023).

Proesmans, W., D. Bonte, G. Smagghe, I. Meeus, and K. Verheyen. (2019). Importance of forest fragments as pollinator habitat varies with season and guild. Basic and Applied Ecology 34: 95–107.

R Core Team. (2022). R: A language and environment for statistical computing. R Foundation of Statistical Computing, Vienna, Austria.

Rooney, T. P., and D. A. Rogers. (2002). The modified floristic quality index. Natural Areas Journal 22: 340–344.

Rosenblatt, D. L., E. J. Heske, S. L. Nelson, D. M. Barber, M. A. Miller, and B. MacAllister. (1999). Forest fragments in east-central Illinois: Islands or habitat patches for mammals? The American Midland Naturalist 141: 115–123.

Rothrock, P. E. (1997). The vascular flora of Fogwell Forest Nature Preserve, Allen County, Indiana. Proceedings of the Indiana Academy of Science 106: 267–290.

Rothrock, P. E. (2004). Floristic quality assessment in Indiana: The concept, use, and development of coefficients of conservatism. Final report for ARN A305-4-53, EPA Wetland Program Development Grant CD975586-01. Indiana Department of Environmental Management, Office of Water Quality, Indianapolis, Indiana, USA. Available online at https://www.lrl.usace.army.mil/Portals/64/docs/regulatory/FloristicAssessment_IND.pdf (Accessed July 31, 2023).

Rothrock, P. E., and M. A. Homoya. (2005). An evaluation of Indiana's floristic quality assessment. Proceedings of the Indiana Academy of Science 114: 9–18

Settle, J., and C. Gonso. (2019). 2019 Indiana forest products price report and trend analysis. The Woodland Steward 28: 1–5.

Spyreas, G. (2019). Floristic quality assessment: A critique, a defense, and a primer. Ecosphere 10: e02825.

Swink, F., and G. Wilhelm. (1994). Plants of the Chicago region. 4th edition. Indiana Academy of Science, Indianapolis, Indiana.

Warners, D. P., G. E. Crow, J. D. Walt, C. R. Koehn, Z. E. Hartwig, and D. Clum. (2021). Botanical assessment of high-quality woodland parcels in the undeveloped Lowell Regional Greenspace, Kent County, Michigan. The Great Lakes Botanist 60: 110–148.

Wilhelm, G. S., T. P. Simon, and P. M. Stewart. (2003). Conservatism of confined disposal facilities based on the biological stability and integrity of plant communities: A case study in the Laurentian Great Lakes basin. Pp. 251–269 in Biological response signatures: Indicator patterns using aquatic communities. T. P. Simon, editor. CRC Press, Boca Raton, Florida.

Wilhite, L. P., and J. R. Toliver. (1990). *Taxodium distichum* (L.) Rich. Baldcypress. Pp. 563–572 in Silvics of North America, Volume 1: Conifers. R. M. Burns and B. H. Honkala, technical coordinators. Agriculture Handbook 654. United States Department of Agriculture, Forest Service, Washington, D.C. Available at https://www.srs.fs.usda.gov/pubs/misc/ag_654/volume_1/taxodium/distichum.htm (Accessed October 10, 2022).

Williams, R. D. (1990). *Juglans nigra* L. Black walnut. Pp. 391–399 in Silvics of North America, Volume 2: Hardwoods. R. M. Burns and B. H. Honkala, technical coordinators. United States Department of Agriculture, Forest Service. Agriculture Handbook 654. United States Department of Agriculture, Forest Service, Washington, D.C. Available at https://www.srs.fs.usda.gov/pubs/misc/ag_654/volume_2/juglans/nigra.htm (Accessed October 10, 2022).

APPENDIX 1. Full list of species encountered at Little Wabash River Nature Preserve in the ecological surveys (column E) and the floristic surveys (column F). Family and scientific names follow ITIS (2023). Non-native species are indicated with a dagger (†) preceding the scientific name. Presence of a species in corresponding surveys is indicated with an 'X'. Presence in a floristic survey in a subsequent visit in 2022 is indicated by an asterisk (*). The voucher numbers refer to specimens deposited in the Purdue University Fort Wayne Department of Biological Sciences herbarium.

Family	Scientific name	E	F	Voucher Number
Adoxaceae	*Sambucus canadensis* L.	X	X	LWRNP0109
Alismataceae	*Alisma subcordatum* Raf.		X	LWRNP0077
Altingiaceae	*Liquidambar styraciflua* L.		X	
Amaryllidaceae	*Allium tricoccum* Sol. var. *burdickii* Hanes		X	LWRNP0137
Anacardiaceae	*Rhus glabra* L.		X	
Anacardiaceae	*Rhus typhina* L.		X	LWRNP0110
Anacardiaceae	*Toxicodendron radicans* (L.) Kuntze	X	X	
Annonaceae	*Asimina triloba* (L.) Dunal		X	
Apiaceae	*Cryptotaenia canadensis* (L.) DC.	X	X	LWRNP0051
Apiaceae	†*Daucus carota* L.	X	X	LWRNP0139
Apiaceae	*Erigenia bulbosa* (Michx.) Nutt.	X	X	LWRNP0003
Apiaceae	*Osmorhiza claytonii* (Michx.) C.B. Clarke	X		
Apiaceae	*Osmorhiza longistylis* (Torr.) DC.		X	LWRNP0224
Apiaceae	†*Pastinaca sativa* L.	X		

APPENDIX 1. (*Continued*).

Family	Scientific name	E	F	Voucher Number
Apiaceae	*Sanicula canadensis* L.	X	X	LWRNP0093
Apocynaceae	*Apocynum cannabinum* L.	X	X	LWRNP0108
Apocynaceae	*Asclepias incarnata* L.		X	
Apocynaceae	*Asclepias quadrifolia* Jacq.		X	
Apocynaceae	*Asclepias syriaca* L.	X	X	LWRNP0078
Araceae	*Arisaema triphyllum* (L.) Schott		X	LWRNP0031
Asparagaceae	†*Asparagus officinalis* L.		X	LWRNP0174
Asparagaceae	†*Convallaria majalis* L.	X	X	LWRNP0043
Asparagaceae	*Maianthemum racemosum* (L.) Link	X	X	LWRNP0053
Asparagaceae	*Polygonatum biflorum* (Walter) Elliott	X	X	LWRNP0047
Aspleniaceae	*Asplenium platyneuron* (L.) Britton, Sterns & Poggenb.	X	X	
Asteraceae	*Achillea millefolium* L.		X	LWRNP0144
Asteraceae	*Ageratina altissima* (L.) R.M. King & H. Rob	X	X	LWRNP0189
Asteraceae	*Ambrosia artemisiifolia* L.	X	X	LWRNP0193
Asteraceae	*Ambrosia trifida* L.		X	
Asteraceae	*Antennaria parlinii* Fernald subsp. *fallax* (Greene) R.J. Bayer & Stebbins		X	LWRNP0012
Asteraceae	†*Arctium minus* (Hill) Bernh.	X		
Asteraceae	*Bidens frondosa* L.		X	LWRNP0232
Asteraceae	†*Cichorium intybus* L.		X	
Asteraceae	†*Cirsium arvense* (L.) Scop.	X	X	LWRNP0083
Asteraceae	†*Cirsium vulgare* (Savi) Ten.		X	
Asteraceae	*Eclipta prostrata* (L.) L.		X	LWRNP0239
Asteraceae	*Erigeron annuus* (L.) Pers.	X	X	LWRNP0237
Asteraceae	*Erigeron philadelphicus* L.		X	LWRNP0241
Asteraceae	*Eupatorium perfoliatum* L.		X	LWRNP0238
Asteraceae	*Euthamia graminifolia* (L.) Nutt.	X	X	LWRNP0236
Asteraceae	*Eutrochium maculatum* (L.) E.E. Lamont		X	
Asteraceae	*Helianthus decapetalus* L.		X	LWRNP0240
Asteraceae	†*Hemerocallis fulva* (L.) L.		X	LWRNP0087
Asteraceae	†*Hieracium piloselloides* Vill.		X	LWRNP0023
Asteraceae	*Lactuca biennis* (Moench) Fernald		X	LWRNP0185
Asteraceae	†*Leucanthemum vulgare* Lam.	X	X	LWRNP0170
Asteraceae	*Packera glabella* (Poir) C. Jeffrey	X		
Asteraceae	*Solidago altissima* L.	X	X	LWRNP0235
Asteraceae	*Solidago canadensis* L. var. *hargeri* Fernald	X	X	LWRNP0234
Asteraceae	*Solidago* sp.	X		
Asteraceae	*Symphyotrichum cordifolium* (L.) G.L. Nesom		X	LWRNP0243
Asteraceae	*Symphyotrichum lanceolatum* (Willd.) G.L. Nesom	X	X	LWRNP0165
Asteraceae	*Symphyotrichum lateriflorum* (L.) Á. Löve & D. Löve		X	LWRNP0242
Asteraceae	*Symphyotrichum novae-angliae* (L.) G.L. Nesom		X	LWRNP0156
Asteraceae	*Symphyotrichum pilosum* (Willd.) G.L. Nesom		X	LWRNP0168
Asteraceae	*Symphyotrichum shortii* (Lindl.) G.L. Nesom	X	X	LWRNP0157
Asteraceae	†*Taraxacum officinale* F.H. Wigg.	X	X	LWRNP0227
Asteraceae	*Verbesina alternifolia* (L.) Britton ex Kearney		X	
Asteraceae	*Vernonia gigantea* (Walter) Trel.	X	X	LWRNP0230
Balsaminaceae	*Impatiens capensis* Meerb.	X	X	LWRNP0138
Berberidaceae	*Podophyllum peltatum* L.		X	LWRNP0049
Betulaceae	*Betula papyrifera* Marshall		X	
Betulaceae	*Carpinus caroliniana* Walter		X	LWRNP0197
Betulaceae	*Ostrya virginiana* (Mill.) K. Koch		X	LWRNP0121

(*Continued on next page*)

APPENDIX 1. (*Continued*).

Family	Scientific name	E	F	Voucher Number
Boraginaceae	*Hackelia virginiana* (L.) I.M. Johnst.		X	LWRNP0141
Brassicaceae	†*Alliaria petiolata* (M. Bieb.) Cavara & Grande	X	X	LWRNP0036
Brassicaceae	†*Barbarea vulgaris* W.T. Aiton		X	LWRNP0213
Brassicaceae	†*Brassica nigra* (L.) W.D.J. Koch		X	
Brassicaceae	*Cardamine concatenata* (Michx.) Sw.	X	X	LWRNP0006
Brassicaceae	*Cardamine douglassii* Britton	X	X	LWRNP0015
Brassicaceae	†*Lepidium campestre* (L.) W.T. Aiton	X	X	LWRNP0035
Campanulaceae	*Campanulastrum americanum* (L.) Small		X	LWRNP0132
Campanulaceae	*Lobelia inflata* L.		X	LWRNP0175
Campanulaceae	*Lobelia siphilitica* L.		X	LWRNP0195
Cannabaceae	*Celtis occidentalis* L.	X	X	LWRNP0113
Caprifoliaceae	†*Lonicera maackii* (Rupr.) Herder	X	X	LWRNP0074
Caprifoliaceae	†*Lonicera* sp.		X	LWRNP0112
Caryophyllaceae	†*Cerastium fontanum* Baumg.	X	X	LWRNP0177
Caryophyllaceae	†*Dianthus armeria* L.		X	LWRNP0204
Caryophyllaceae	†*Stellaria media* (L.) Vill.	X	X	LWRNP0225
Celastraceae	*Euonymus atropurpureus* Jacq.	X		
Convulvulaceae	†*Calystegia silvatica* (Kit.) Griseb.		X	LWRNP0167
Cornaceae	*Cornus drummondii* C.A. Mey	X	X	LWRNP0104
Cornaceae	*Cornus racemosa* Lam.	X	X	LWRNP0084
Cucurbitaceae	*Echinocystis lobata* (Michx.) Torr. & A. Gray		X	LWRNP0172
Cupressaceae	*Juniperus virginiana* L.		X	
Cupressaceae	*Taxodium distichum* (L.) Rich. var. *distichum*		X	
Cyperaceae	*Carex blanda* Dewey		X	LWRNP0194
Cyperaceae	*Carex granularis* Muhl. ex Willd.	X	X	LWRNP0181
Cyperaceae	*Carex hirtifolia* Mack.		X	LWRNP0190
Cyperaceae	*Carex jamesii* Schwein.	X	X	LWRNP0044
Cyperaceae	*Carex laevivaginata* (Kük.) Mack.		X	LWRNP0082
Cyperaceae	*Carex normalis* Mack.	X	X	LWRNP0183
Cyperaceae	*Carex oligocarpa* Schkuhr ex Willd.		X	LWRNP0208
Cyperaceae	*Carex rosea* Schkuhr ex Willd.		X	LWRNP0199
Cyperaceae	*Carex shortiana* Dewey		X	LWRNP0179
Cyperaceae	*Carex sparganioides* Muhl. ex Willd.		X	LWRNP0205
Cyperaceae	*Carex stipata* Muhl. ex Willd.	X	X	LWRNP0196
Cyperaceae	*Carex tribiloides* Wahlenb.		X	
Cyperaceae	*Carex vulpinoidea* Michx.	X	X	LWRNP0201
Cyperaceae	*Scirpus atrovirens* Willd.	X	X	LWRNP0130
Dioscoreaceae	*Dioscorea villosa* L.		X	
Dryopteridaceae	*Dryopteris carthusiana* (Vill.) H.P. Fuchs		X	LWRNP0056
Dryopteridaceae	*Polystichum acrostichoides* (Michx.) Schott		X	LWRNP0055
Ebenaceae	*Diospyros virginiana* L.		X	
Elaeagnaceae	†*Elaeagnus umbellata* Thunb.	X	X	LWRNP0026
Equisetaceae	*Equisetum arvense* L.		X	LWRNP0009
Ericaceae	*Monotropa uniflora* L.		X	LWRNP0192
Fabaceae	*Amphicarpaea bracteata* (L.) Fernald		X	LWRNP0166
Fabaceae	*Cercis canadensis* L.	X	X	LWRNP0118
Fabaceae	*Desmodium paniculatum* (L.) DC.		X	LWRNP0202
Fabaceae	*Gleditsia triacanthos* L.		X	LWRNP0101
Fabaceae	†*Medicago sativa* L.	X		
Fabaceae	†*Securigera varia* (L.) Lassen		X	LWRNP0114
Fabaceae	†*Trifolium pratense* L.	X	X	LWRNP0052
Fabaceae	†*Trifolium repens* L.	X	X	LWRNP0146
Fagaceae	*Quercus alba* L.	X	X	

APPENDIX 1. (*Continued*).

Family	Scientific name	E	F	Voucher Number
Fagaceae	*Quercus bicolor* Willd.	X	X	LWRNP0075
Fagaceae	*Quercus coccinea* Münchh.		X	
Fagaceae	*Quercus muehlenbergii* Engelm.		X	
Fagaceae	*Quercus rubra* L.	X	X	LWRNP0091
Papaveraceae	*Dicentra canadensis* (Goldie) Walp.		X	LWRNP0008
Papaveraceae	*Dicentra cucullaria* (L.) Bernh.		X	LWRNP0001
Geraniaceae	*Geranium maculatum* L.	X	X	LWRNP0038
Grossulariaceae	*Ribes cynosbati* L.	X	X	LWRNP0014
Hydrophyllaceae	*Hydrophyllum appendiculatum* Michx.	X	X	LWRNP0048
Hydrophyllaceae	*Hydrophyllum macrophyllum* Nutt.	X	X	LWRNP0057
Hydrophyllaceae	*Hydrophyllum virginianum* L.		X	LWRNP0218
Hydrophyllaceae	*Phacelia bipinnatifida* Michx.		X	
Hypericaceae	†*Hypericum perforatum* L.		X	LWRNP0134
Hypericaceae	*Hypericum punctatum* Lam.		X	LWRNP0217
Iridaceae	*Sisyrinchium angustifolium* Mill.		X	LWRNP0028
Juglandaceae	*Carya cordiformis* (Wangenh.) K. Koch	X	X	
Juglandaceae	*Carya ovata* (Mill.) K. Koch		X	
Juglandaceae	*Juglans nigra* L.		X	
Juncaceae	*Juncus tenuis* Willd.	X	X	LWRNP0067
Lamiaceae	*Agastache nepetoides* L.		X	LWRNP0184
Lamiaceae	*Blephilia hirsuta* (Pursh) Benth.	X		
Lamiaceae	*Collinsonia canadensis* L.		X	LWRNP0182
Lamiaceae	†*Glechoma hederacea* L.	X	X	LWRNP0050
Lamiaceae	*Lycopus americanus* Muhl. ex W.P.C. Barton		X	LWRNP0200
Lamiaceae	*Monarda fistulosa* L.		X	LWRNP0097
Lamiaceae	*Monarda serotina nom. illeg.*		X	LWRNP0250
Lamiaceae	†*Origanum vulgare* L.		X	LWRNP0088
Lamiaceae	*Prunella vulgaris* L.	X	X	LWRNP0090
Lamiaceae	*Stachys tenuifolia* Willd.		X	LWRNP0224
Lamiaceae	*Teucrium canadense* L.		X	LWRNP0092
Lauraceae	*Lindera benzoin* (L.) Blume		X	LWRNP0158
Liliaceae	*Erythronium albidum* Nutt.		X	LWRNP0007
Liliaceae	*Erythronium americanum* Ker Gawl.	X	X	LWRNP0002
Limnanthaceae	*Floerkea proserpinacoides* Willd.	X	X	LWRNP0032
Magnoliaceae	*Liriodendron tulipifera* L.		X	LWRNP0073
Malvaceae	*Tilia americana* L.		X	LWRNP0105
Melanthiaceae	*Trillium sessile* L.		X	LWRNP0010
Menispermaceae	*Menispermum canadense* L.	X	X	LWRNP0058
Montiaceae	*Claytonia virginica* L.	X	X	LWRNP0005
Moraceae	†*Morus nigra* L.		X	
Moraceae	*Morus rubra* L.		X	LWRNP0020
Myrsinaceae	*Lysimachia quadrifolia* L.		X	LWRNP0122
Oleaceae	*Fraxinus pennsylvanica* Marshall	X		
Oleaceae	*Fraxinus quadrangulata* Michx.	X	X	LWRNP0159
Onagraceae	*Circaea canadensis* (L.) Hill	X	X	LWRNP0145
Onagraceae	*Circaea lutetiana* L.	X		
Onagraceae	*Epilobium coloratum* Biehler		X	LWRNP0169
Onagraceae	*Ludwigia palustris* (L.) Elliott		X	LWRNP0215
Onocleaceae	*Onoclea sensibilis* L.		X	LWRNP0054
Ophioglossaceae	*Botrychium virginianum* (L.) Sw.		X	LWRNP0080
Ophioglossaceae	*Ophioglossum vulgatum* L.		X	LWRNP0076
Orchidaceae	*Liparis liliifolia* (L.) Rich. ex Ker Gawl.		X	

(*Continued on next page*)

APPENDIX 1. (*Continued*).

Family	Scientific name	E	F	Voucher Number
Orchidaceae	*Spiranthes cernua* (L.) Rich.		X	LWRNP0251
Orchidaceae	*Spiranthes lacera* (Raf.) Raf. var. *gracilis* (Bigelow) Luer		X	LWRNP0162
Orchidaceae	*Spiranthes magnicamporum* Sheviak		*	
Orchidaceae	*Spiranthes ovalis* Lind.		*	
Oxalidaceae	*Oxalis dillenii* Jacq.	X	X	LWRNP0143
Papaveraceae	*Sanguinaria canadensis* L.		X	
Penthoraceae	*Penthorum sedoides* L.		X	LWRNP0149
Phrymaceae	*Mimulus ringens* L.		X	LWRNP0180
Phrymaceae	*Phryma leptostachya* L.	X	X	LWRNP0136
Phytolaccaceae	*Phytolacca americana* L.		X	LWRNP0178
Pinaceae	*Picea glauca* (Moench) Voss		X	
Pinaceae	*Pinus strobus* L.	X	X	
Plantaginaceae	†*Plantago lanceolata* L.	X	X	LWRNP0024
Plantaginaceae	*Plantago rugelii* Decne.	X		
Plantaginaceae	†*Veronica serpyllifolia* L. subsp. *serpyllifolia*		X	LWRNP0220
Platanaceae	*Platanus occidentalis* L.		X	
Poaceae	†*Agrostis gigantea* Roth	X	X	LWRNP0207
Poaceae	†*Bromus inermis* Leyss.		X	LWRNP0216
Poaceae	*Bromus pubescens* Muhl. ex Willd.	X	X	LWRNP0081
Poaceae	†*Dactylis glomerata* L.	X	X	LWRNP0210
Poaceae	*Dichanthelium boscii* (Poir.) Gould & C.A. Clark	X	X	LWRNP0085
Poaceae	*Dichanthelium linearifolium* (Scribn. ex Nash) Gould	X		
Poaceae	†*Echinochloa crus-galli* (L.) P. Beauv.		X	
Poaceae	*Elymus canadensis* L.		X	LWRNP0071
Poaceae	*Elymus hystrix* L.	X	X	LWRNP0129
Poaceae	*Elymus virginicus* L. var. *virginicus*		X	LWRNP0209
Poaceae	*Glyceria striata* (Lam.) Hitchc.	X	X	LWRNP0249
Poaceae	*Leersia virginica* Willd.		X	LWRNP0219
Poaceae	†*Phleum pratense* L.	X	X	LWRNP0068
Poaceae	†*Poa pratensis* L. subsp. *pratensis*	X	X	LWRNP0221
Poaceae	*Poa sylvestris* A. Gray	X	X	LWRNP0223
Polemoniaceae	*Phlox divaricata* L.		X	LWRNP0039
Polemoniaceae	*Polemonium reptans* L.		X	LWRNP0037
Polygonaceae	*Fallopia scandens* (L.) Holub		X	LWRNP0173
Polygonaceae	*Persicaria punctata* (Elliott) Small		X	LWRNP0247
Polygonaceae	*Persicaria virginiana* (L.) Gaertn	X	X	LWRNP0176
Primulaceae	*Lysimachia ciliata* L.		X	LWRNP0229
Ranunculaceae	*Actaea pachypoda* Elliott	X	X	LWRNP0046
Ranunculaceae	*Anemone canadensis* L.	X		
Ranunculaceae	*Ranunculus abortivus* L.	X	X	LWRNP0016
Ranunculaceae	†*Ranunculus ficaria* L.		X	LWRNP0030
Ranunculaceae	*Ranunculus hispidus* Michx.		X	LWRNP0045
Ranunculaceae	*Ranunculus recurvatus* Poir.	X	X	LWRNP0017
Rosaceae	*Agrimonia pubescens* Wallr.		X	LWRNP0228
Rosaceae	*Crataegus* sp.		X	LWRNP0233
Rosaceae	†*Duchesnea indica* (Andrews) Focke var. *indica*	X		
Rosaceae	*Fragaria vesca* L.	X		
Rosaceae	*Fragaria vesca* L. subps. *vesca*	X		
Rosaceae	*Fragaria virginiana* Duchesne subsp. *grayana* (E. Vilm. ex J. Gray) Staudt		X	LWRNP0059
Rosaceae	*Geum canadense* Jacq.	X	X	LWRNP0065
Rosaceae	*Geum* sp.	X		

APPENDIX 1. (*Continued*).

Family	Scientific name	E	F	Voucher Number
Rosaceae	*Geum vernum* (Raf.) Torr. & A. Gray	X	X	LWRNP0040
Rosaceae	†*Potentilla recta* L.		X	LWRNP0135
Rosaceae	*Prunus serotina* Ehrh.	X	X	LWRNP0107
Rosaceae	†*Rosa multiflora* Thunb.	X	X	LWRNP0212
Rosaceae	*Rosa setigera* Michx. var. *tomentosa* Torr. & A. Gray		X	LWRNP0246
Rosaceae	*Rosa* sp.		X	LWRNP0248
Rosaceae	*Rubus occidentalis* L.	X	X	LWRNP0211
Rubiaceae	*Galium aparine* L.	X	X	LWRNP0061
Rubiaceae	*Galium asprellum* Michx.	X		
Rubiaceae	*Galium circaezans* Michx.	X	X	LWRNP0063
Rubiaceae	*Galium concinnum* Torr. & A. Gray	X	X	LWRNP0086
Rubiaceae	*Galium triflorum* Michx.	X	X	LWRNP0119
Salicaceae	*Populus deltoides* W. Bartram ex Marshall		X	
Salicaceae	*Salix nigra* Marshall		X	LWRNP0111
Sapindaceae	*Acer negundo* L.		X	LWRNP0198
Sapindaceae	*Acer saccharinum* L.		X	
Sapindaceae	*Acer saccharum* Marshall	X	X	LWRNP0019
Sapindaceae	*Aesculus glabra* Willd.	X	X	LWRNP0072
Scrophulariaceae	*Scrophularia marilandica* L.		X	
Smilacaceae	*Smilax ecirrhata* S. Watson		X	LWRNP0100
Smilacaceae	*Smilax* sp.	X		
Smilaceae	*Smilax tamnoides* L.	X	X	LWRNP0226
Solanaceae	*Physalis longifolia* Nutt.		X	LWRNP0131
Solanaceae	*Solanum carolinense* L.	X	X	LWRNP0245
Ulmaceae	*Ulmus americana* L.	X	X	LWRNP0120
Ulmaceae	*Ulmus rubra* Muhl.		X	LWRNP0152
Urticaceae	*Boehmeria cylindrica* (L.) Sw.	X	X	LWRNP0186
Urticaceae	*Laportea canadensis* (L.) Benth.	X	X	
Urticaceae	*Pilea pumila* (L.) A. Gray	X	X	LWRNP0140
Urticaceae	*Urtica dioica* L.		X	
Verbenaceae	*Verbena urticafolia* L.		X	
Violaceae	*Viola pubescens* Aiton		X	LWRNP0011
Violaceae	*Viola sororia* Willd.	X	X	LWRNP0095
Violaceae	*Viola striata* Aiton	X	X	LWRNP0093
Vitaceae	*Parthenocissus quinquefolia* (L.) Planch.	X	X	LWRNP0034
Vitaceae	*Vitis vulpina* L.	X	X	LWRNP0222