PLANT INVASION AND BIODIVERSITY PATTERNS AT A MARYLAND PRESERVE

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ABSTRACT

The Audubon Society of Central Maryland's 55-hectare Fred J. Archibald Audubon Sanctuary in Maryland's Piedmont physiographic region is an important wildlife habitat under threat from residential and commercial development that will soon be encroaching on all sides. The potential fostering of nonnative plant species by this development poses a significant risk to native plant biodiversity at the preserve, with resulting impacts to higher trophic levels, particularly phytophagous insects and insectivorous birds. Plant communities in 12 field and forest stands throughout the preserve were sampled for species presence/absence and percent cover. Various biodiversity measures were calculated for each habitat, including richness, alpha diversity, beta diversity, and nonnative cover. Three nonnative plant species in particular were found to be encroaching on certain plant communities at the preserve: *Microstegium vimineum* (Japanese stiltgrass), *Persicaria longiseta* (oriental smartweed), and *Celastrus orbiculatus* (Oriental bittersweet), of which the latter may present the most substantial concern, especially to the overstory of forested stands. Although nonnative cover was high in certain stands, pockets of native biodiversity persisted, suggesting the continued importance of these areas to native fauna. Combinations of native and nonnative diversity measures present a potential schema for assigning management regimes to stands, with strategies ranging from low to intense levels of management.

DEDICATION

To Zoe, Luke, and Wyatt: May my contributions help to make Earth a better place for yours and future generations.

ACKNOWLEDGEMENTS AND SPONSORSHIP

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INTRODUCTION

The Audubon Society of Central Maryland's 55-hectare Fred J. Archibald Audubon Sanctuary (39.401353°, -77.280011°; hereafter, FAAS) is an important habitat for many species of wildlife native to Maryland's Piedmont physiographic region. More than 100 bird species have been documented at the preserve, including several forest birds undergoing population declines, migratory birds that pass through in spring and fall, and many other species that use the area as breeding and winter grounds (Schaefer 2014). However, significant changes may be on the horizon for at least some of the wildlife species. The native plants within FAAS that provide shelter and food are under threat from multiple nonnative invasive plant species. This problem will likely be exacerbated in the coming years, given that 2,000 homes are slated to be built in three new residential developments bordering FAAS, along with two roads to be built directly north and south of the preserve (Figure 1), the southern of which will separate the preserve from a publicly owned 75-acre parcel of mature woodland.

The planned developments could alter the native plant community at FAAS via several mechanisms. Gardens planted in the backyards of future homes present a potentially substantial concern. The deliberate introduction of horticultural and ornamental plants is the source of the majority of nonnative plant species in the U.S. (Mack and Erneberg 2002), and gardens and garden waste supply plentiful seeds of invasive species to nearby natural areas (Bar-Massada et al. 2014, Catford et al. 2011). In the study site area, this propagule advantage will likely be amplified in the disturbed areas that will result from housing and road construction, including the edges joining the developed land and the preserve. Many of the nonnative species favored in horticulture possess traits that enable them to thrive in early succession (Martin et al. 2009), and many invasive species readily colonize disturbed areas, particularly abandoned farm fields, and
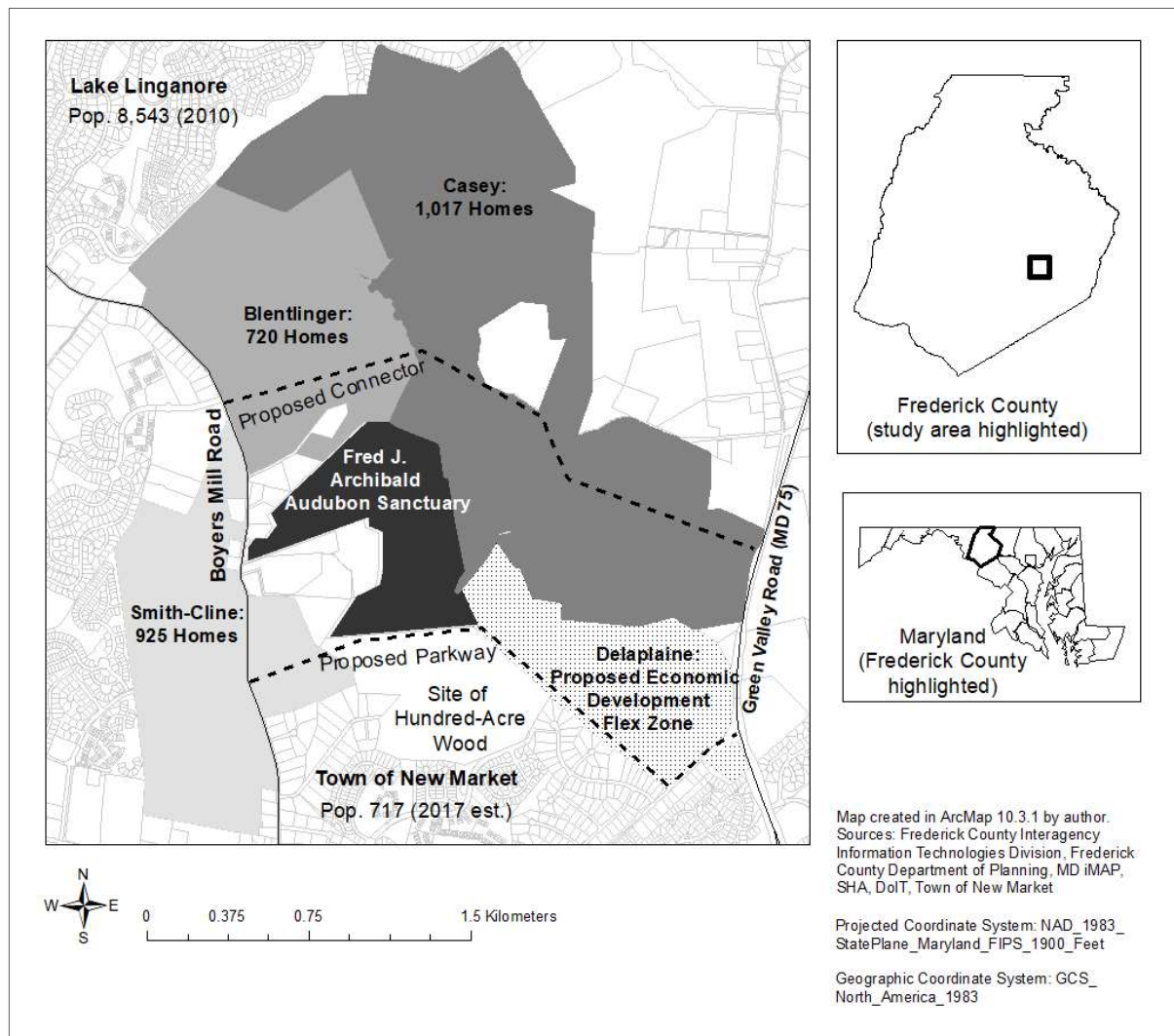
Figure 1. Under current development plans, more than 2,000 new homes and an economic development zone will someday encircle the Fred J. Archibald Audubon Sanctuary north of New Market, Maryland. (Property name and planned number of houses are depicted for each development.) In addition, two new roads (dashed lines) will extend north and south of the preserve, while additional roads (not shown on map) will be built to serve the developments, and Boyers Mill Road will be widened. Boundaries shown are approximate and are not intended to represent legal boundaries.

forest edges (Blumenthal 2005, Brothers and Springarn 1992, Foxcroft et al. 2011, Fraver 1994, Honnay et al. 2002, Matlack 1994, Meiners and Pickett 1999, Moles et al. 2012). According to the resource-enemy release hypothesis, this pattern occurs because exotic species do not face pressure from the specialist herbivores and pathogens found in their native environments, and

they therefore benefit the most from the increased resources (e.g., light and space) available in disturbed habitats, which they can invest in growth instead of enemy defense (Blumenthal 2005).

In addition to creating disturbance conditions that may foster plant invasions, the developments may increase the influence of vectors that carry invasive plants to FAAS, including vehicle tires and roads and other impervious surfaces (Foxcroft et al. 2011, von der Lippe and Kowarik 2007), as well as wildlife that consume invasive plant propagules, particularly fleshy fruits, or that aid pollination in exchange for floral resources (Bartuszevige and Gorchov 2006, Goodell et al. 2010, Simberloff and Von Holle 1999). If habitat loss in the adjacent areas drives seed-dispersing species into the interior of FAAS, wildlife-aided distribution of invasive seeds could increase, at least initially. Also, high populations of free-roaming domesticated cats in the developed areas could impact seed dispersal by altering the foraging and movement patterns of prey species (Bar-Massada et al. 2014).

The impacts of increased plant invasion at FAAS could be significant. Simberloff et al. (2012) found that nonnative plant species in the U.S. are 40 times more likely to be classified as invasive, defined by the authors as any species that enters a natural or semi-natural area and has some impact on the resident species. While changes to overall native plant diversity following invasion are variable (Vellend 2017), individual native species or groups of native species may be lost through competition with nonnative species or with hybrid offspring (Simberloff and Von Holle 1999). In some cases, invasional meltdowns result when nonnative species become biologically integrated and facilitate each other's establishment or spread (Simberloff and Von Holle 1999).

The resulting impacts to food webs can be severe. There is evidence that at least some pollinators are able to obtain floral resources from nonnative plants (Drossart et al. 2017, Giovanetti et al. 2015, Jakobsson and Padron 2014); however, in the case of phytophagous insects, the vast majority require host plants with which they share an evolutionary history (Tallamy 2004). These organisms, many of which are specialists associated with one or a few plant species, face a barrier in the novel secondary compounds of nonnative plants. The Lepidoptera are especially affected, as nonnative genera have been found to support four times fewer native species in this order than do native genera (Tallamy and Shropshire 2009). The "pest-free" qualities of many nonnative ornamentals have led horticulturists to selectively favor these plants over native species that experience more frequent herbivory (Burghardt et al. 2009). The result has been characterized as a transformation of millions of acres of prime habitat into "food deserts" for native insects (Narango et al. 2018).

This change at the first trophic level may be particularly detrimental to terrestrial birds, the majority of which require insects during reproduction and other periods of nutrient limitation, even if they are sustained by berries and seeds of nonnative plants during other periods (Narango et al. 2018). The implications of these impacts are especially severe given that they are occurring during a time of unprecedented declines in avian and arthropod taxa (Rosenberg et al. 2019, Sanchez-Bayo and Wyckhuys 2019). In the face of global biodiversity losses, conservation of habitats such as the Audubon preserve may prove particularly important to sustaining local populations of native flora and fauna.

A looming question regarding the impacts of invasive species is the role that climate change will play in their distribution and spread. Although the impacts of climate change on

native and nonnative species, their interactions, and the resulting ecological implications are difficult to predict, warming temperatures may bring the arrival of new ornamental species that previously grew in more southern climes, some of which will undoubtedly have the capacity to naturalize and become invasive (Bradley et al. 2010). The increased winter and early spring rain and snow predicted for North America may favor invasive species, which have adapted to quickly respond to such resource fluxes (Blumenthal et al. 2008). Rahel et al. (2008) suggest that the dual stressors of climate change and invasive species should propel managers to adopt more active approaches to conserving threatened native species.

Statement of Study Objectives

The main assumption underlying the current study is that, given the extent and location of the planned development for the areas adjacent to the Fred J. Archibald Audubon Sanctuary, the preserve is at risk of further plant invasions, loss of native plant species, floristic homogenization, and negative impacts to native wildlife, particularly insectivorous birds. Therefore, there is a need to measure baseline characteristics of the first trophic level at the preserve, prior to any changes the planned developments may set in motion.

Vegetation sampling was undertaken at FAAS during the 2019 growing season with the following objectives:

1. Measure various aspects of plant biodiversity in each of 12 stands throughout the preserve and identify key characteristics of each, for example, whether any stands are homogeneous or especially distinct. These measures can help managers create tailored strategies for each stand according to desired management objectives. They also will

establish a baseline against which post-development data can be compared to see whether patterns of diversity and invasion are changing.

2. Map the intensity of plant invasions in each stand, to reveal potential spatial patterns. These results will provide information to preserve managers in determining which stands and invasive species to target. The map will help determine whether plant communities that are particularly critical to wildlife, such as the fields of warm-season grasses, are under imminent threat of invasion from adjacent stands.

3. Produce a checklist of vascular plants. As with the other results, this checklist can be compared with information gathered after development, to assess which species have been lost or gained. Knowing more about the species present at the preserve also can help managers target efforts for conservation, as plant species differ in their value to wildlife.

MATERIALS AND METHODS

Study Site Description

The Fred J. Archibald Audubon Sanctuary is located in the Maryland Piedmont physiographic region, approximately 30 km east of the Catoctin Mountain range. Average annual temperatures in the area range from 7.7°C to 19.2°C, and annual precipitation averages 103 cm. The topography is typical of the regional landscape, moderately hilly with steep riparian areas. The most prominent soil type is Linganore-Hyattstown channery silt loam, 3 to 8 percent slopes, a well-drained soil with medium runoff potential and high capacity for growing oaks and associated hardwoods. Ten other soil types have been mapped, including other channery silt loams, channery loams, silt loams, and gravelly loams, with slopes ranging from 0 to 45 percent.

Former military officer and journalist Fred J. Archibald donated the property to the Audubon Society of Central Maryland upon his death in 2002. The parcel was one of several contiguous properties co-owned by Archibald on which cattle and crops were raised. Today, the property comprises a mosaic of habitats, reflecting a management objective of fostering habitat diversity and successional edges to serve different species and needs of wildlife (Schaefer 2014).

Although much of the land was farmed back to a time predating Archibald, several forest stands have been in existence for decades. Forest Stands 1, 2, and 3 contain former pasturelands abandoned as long as 90+, 70+, and 30+ years ago, respectively (Seipp et al 2002). The pasture that preceded Forest Stand 4 was more recently abandoned, and today the stand contains a mix of successional species, while Fields 5, 6, and 7 also are undergoing early stages of succession (Durcho 2018, Schaefer 2014). In 2005, Fields 1, 2, and 4 were planted in native warm-season grasses. These fields contain scattered bushes and small trees and are maintained via annual

mowing and spot treatment of invasives. Regular mowing also maintains paths around many of the stands at FAAS.

Sampling Methods

A map of FAAS (Figure 2) was created using parcel and stream data downloaded from the Frederick County government. In ArcMap, stands were traced with the polygon drawing tool over the World Imagery basemap from ESRI and other sources, guided by boundaries visible on the satellite imagery as well as field reconnaissance, historic aerial photographs, and stand delineation maps from the Audubon Society of Central Maryland (Schaefer 2014) and the Maryland Department of Natural Resources (Seipp et al. 2002, Durcho 2018). The polygons were converted to features and the attribute table of the resulting feature class was edited to include the name of each plant community (as assigned by Maryland DNR) as well as the habitat type (forest or field). The habitat types were then symbolized as either forest or field and the name of each stand displayed as a label.

Plot locations were then selected via a stratified random sampling design. In each habitat previously delineated by DNR, 3-5 plots were randomly located in ArcMap (Figure 2) using the Create Random Points tool, constrained to the stands feature class, with the number of points in each stand specified in the map's attribute table. The 41 total plots represent a sampling intensity of 0.79 percent of the total area.

Sampling occurred over three weeks in July and August 2019 with the help of volunteers recruited from Audubon Society of Central Maryland, the University of Maryland Extension
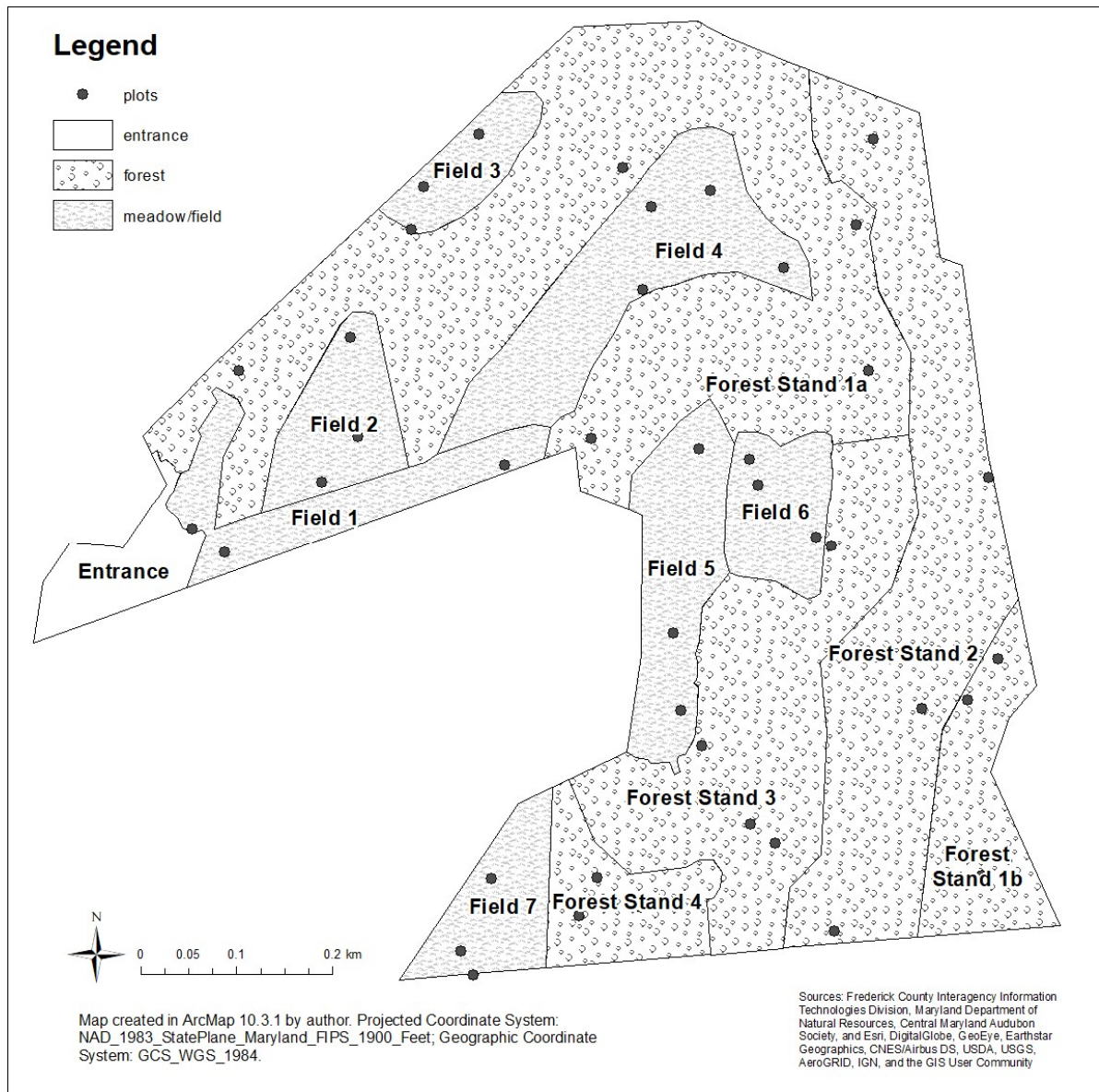
Figure 2. Plant community sampling occurred in 41 plots throughout 12 stands at the Fred J. Archibald Audubon Sanctuary. Plot symbols are not drawn to scale.

Master Naturalists program, and elsewhere. Sampling was done within 168-m^2 circular plots

centered on the randomly located points, using a protocol slightly modified from those used by

the National Forest Service Inventory and Analysis Program (Barnett et al. 2007; Figure 3).

Within each plot, 1m x 1m quadrats were established within a Daubenmire frame placed at 4.6 m from the center on 30°, 150°, and 270° azimuths. Poles were used to divide the subplots into quadrants to aid estimation. Within the subplots, each species was identified and its percent cover estimated. Total percent cover of all species within a subplot typically did not add to 100 percent due to the existence of spatial layers or the presence of bare ground and coarse woody debris. Within the larger plot, species were merely identified, without accompanying quantitative information. Only plants that were rooted in the plots or subplots were included in the results. Searching time was

Figure 3. Sampling occurred within circular plots containing nested 1-m² square subplots. Figure based on Barnett et al. 2007.

constrained to two hours per plot. Digital photographs preserved a record of each species and were uploaded to a project database created on iNaturalist.org. Specimens of more common and/or abundant species that could not be identified definitively in the field were collected, pressed, and identified in the lab using floral keys and a dissecting microscope. They are preserved in the Hood College herbarium.

Analytical Methods

Objective #1: Analyze diversity in each stand. The following calculations measured various aspects of plant biodiversity within each stand at the preserve.

Total number of species. A cumulative list of species recorded in all the plots and subplots of each stand was compiled. The total number of species in each stand was also divided by the total number of species recorded in the study (217), to provide a measure of the stand's contribution to overall plant richness at the preserve.

Total number of species/100 m². As sampling area differed among stands, and total species richness might be more a function of sampling area than inherent stand differences, the total number of species in each stand was divided by the area of the stand, in units of 100 m², to provide a standardized measure of species richness. The number of plots in each stand was multiplied by 128 m² to calculate the sampling area within each stand.

Total number of native species. Species were coded as either native or nonnative as classified by the Maryland Biodiversity Project (2019). The nonnative species were removed from the results, and a cumulative list of native species recorded in all the plots and subplots of each stand was then compiled.

Total number of native species/100 m². The total number of native species in each stand was divided by the area of the stand, in units of 100 m², to provide a standardized measure of native species richness.

Relative native richness. The number of native species documented in each habitat was divided by the total number of species identified in that stand, to provide an indication of how well native species were represented in the plant community.

Unique species. The unique species recorded in each stand—i.e., the species found only in that stand—were counted to provide a measure of the stand's uniqueness and importance to locally rare plants.

Unique species/100 m². The number of unique species in each stand was divided by the sampling area of each stand, in units of 100 m², to provide an area-weighted measure of unique species.

Diversity indices. The percent cover of each species was averaged across all the subplots of a plot to provide an estimate of species cover for a single plot. The "vegan" package in the R statistical program was used to calculate overall Simpson's and Shannon-Weiner diversity in each plot based on these cover data. These indices are calculated with the following formulas:

Simpson's   Shannon-Weiner

$$D = \Sigma \frac{N(N-1)}{n_i(n_i-1)} \qquad\qquad H' = -\Sigma \left(\frac{n_i}{N}\right)\left(ln\left(\frac{n_i}{N}\right)\right)$$

where D = Simpson's diversity, H' = Shannon-Weiner diversity, N = the total abundance of species, and n = the abundance of species i. Simpson's diversity scores range from 0 to 1, and Shannon-Weiner scores typically range from ~1 to 4; in both cases, higher diversity results in higher scores.

Once the diversity scores were calculated for all plots, they were averaged across all the plots of a stand to provide an estimate of the diversity in that stand. Native Shannon-Weiner and Simpson's diversity were calculated by removing nonnative species from the subplot results.

Percent cover nonnative species. To determine the total percent cover of nonnative species in each stand, the percentages of all nonnative species in each subplot were added, and these sums were averaged across all of the subplots of a plot to provide an estimate of the total nonnative cover for the plot. The total nonnative cover was then averaged across all of the plots of the stand to provide an estimate of the total nonnative cover of the stand.

Invasion risk and recovery potential. Native Simpson's diversity of each stand was plotted against the total percent cover of nonnative species in each stand to provide a measure of the stand's invasion risk and recovery potential. Linear regression analysis was conducted in SPSS to test the statistical significance of the relationship between these two variables.

Dominance diversity curves. For each stand, species were sorted from lowest to highest percent cover and presented on the *x*-axis, with the cumulative percent cover achieved with each successive species presented on the *y*-axis. The area under the curve represents the total cover of all species recorded in the quadrats of the stand.

Jaccard index. This value quantifies beta diversity, or the amount of overlap in species composition between two stands, and is represented by:

$$J = \frac{A}{A + B + C}$$

where A = the number of species found in both stands, B = species in stand 1 only, and C = species in stand 2 only. The "vegan" package in R was used to construct the Jaccard matrix.

Objective #2: Map spatial patterns in plant invasions.

Nonnative cover results, calculated as described previously, provided additional data for the stands map, and a standard deviation classification was used to shade each stand according to its total percent cover of nonnative species.

To determine the three most dominant nonnative species across the preserve as a whole, the average percent cover of each nonnative species across the three subplots in each plot was calculated. The average percent cover of each species across all 41 plots was then calculated and

the data sorted by average percent cover. Bar charts were used to symbolize the degree of invasion by these three species in each plant community.

Objective #3: Produce a checklist of vascular plants.

A master table was constructed to present all of the species recorded in the subplots and plots, consisting of scientific and common names, native status, plant family, a series of 1s and 0s to indicate presence or absence in each of the 41 plots, and frequency, or the number of plots in which each species was documented. The list was sorted by plant family and, within plant family, by scientific names. Nomenclature, taxonomy, and native status follow the Maryland Biodiversity Project (2019).

RESULTS

Objective #1: Analyze plant diversity in each stand.

The results of the richness analyses are presented in Table 1. A total of 217 plant species were documented, 202 of which could be identified to species or genus with reasonable confidence. Of the latter, 144 were species native to Maryland and 53 were species not native to Maryland, as classified by the Maryland Biodiversity Project (2019). An average of 12.98 species/100 m² were documented in the sampled areas of each stand, with the standardized number of species ranging from a low of 8.63 in Field 4 to a high of 17.46 in Forest Stand 4 and with multiple stands clustered in the low end of this range. Stands contributed an average of 34 percent of the total species; the stand with the lowest nonstandardized number of species, Field 1, contributed 27 percent of the total species, while the stand with the highest nonstandardized number of species, Forest Stand 4, contributed 41 percent of the total.

Table 1: Plant Richness Measures in Sampled Areas

Stand	# Total Species	#Total Species/ 100 m²	# Native Species	# Native Species/ 100 m²	Percent of Overall Richness	Relative Native Richness	Unique Species	Unique Species/ 100 m²
FS 1a	86	10.24	63	7.50	0.40	0.73	4	0.48
FS 1b	60	11.90	45	8.93	0.28	0.75	1	0.20
FS 2	78	11.61	60	8.93	0.36	0.77	16	2.38
FS 3	79	11.76	53	7.89	0.36	0.67	5	0.74
FS 4	88	17.46	52	10.32	0.41	0.59	1	0.20
Field 1	59	11.71	38	7.54	0.27	0.64	3	0.60
Field 2	81	16.07	57	11.31	0.37	0.70	3	0.60
Field 3	87	17.26	39	7.74	0.40	0.45	1	0.20
Field 4	58	8.63	40	5.95	0.27	0.69	0	0.000
Field 5	73	14.48	43	8.53	0.34	0.59	1	0.20
Field 6	75	14.88	48	9.52	0.35	0.64	2	0.40
Field 7	70	13.89	38	7.54	0.32	0.54	1	0.20
Average	74.5	12.98	48.00	8.36	0.34	0.65	3.17	0.55

There was a standardized average of 8.36 native species/100 m^2 in each stand, ranging

from 5.95 (Field 4) to 11.31 (Field 2), and multiple stands again were clustered at the lower end

of the range. Relative native richness, representing the native component of a stand's total

species richness, ranged from 0.45 (Field 3) to 0.77 (Forest Stand 2), with an average of 0.65 and

a more normal distribution than with the previous three statistics. Stands averaged 0.55 unique

species/100 m^2, ranging from 0 (Field 4) to 2.38 (Forest Stand 2).

Diversity indices present a more comprehensive measure of biodiversity, as they

incorporate not just species counts but species evenness, or the relative dominance of the species

within plots. Shannon-Weiner diversity in stands averaged 1.99, ranging from 1.61 (Forest Stand

1a) to 2.31 (Field 2), and Simpson's diversity averaged 0.77, ranging from 0.67 (Forest

Stand 1a) to 0.85 (Field 6) (Table 2).

When nonnative species were filtered out, Shannon diversity averaged 1.64, ranging

Table 2: Plant Diversity Measures in Sampled Areas

Stand	Overall Shannon Diversity	Overall Simpson's Diversity	Native Shannon Diversity	Native Simpson's Diversity	Percent Cover Nonnative Species
FS 1a	1.61	0.67	1.66	0.70	0.49
FS 1b	2.01	0.79	1.36	0.70	0.23
FS 2	1.80	0.73	1.26	0.64	0.24
FS 3	1.80	0.71	1.59	0.66	0.71
FS 4	1.98	0.77	1.94	0.59	0.65
Field 1	2.16	0.81	1.99	0.60	0.29
Field 2	2.31	0.83	2.05	0.61	0.19
Field 3	2.22	0.83	1.70	0.62	0.70
Field 4	1.81	0.74	1.61	0.61	0.06
Field 5	1.74	0.72	1.36	0.65	0.25
Field 6	2.27	0.85	1.80	0.67	0.42
Field 7	2.14	0.81	1.38	0.69	0.45
Average	1.99	0.77	1.64	0.65	0.39

from 1.26 (Forest Stand 2) to 2.05 (Field 2), and Simpson's diversity averaged 0.65, ranging

from 0.59 (Forest Stand 4) to 0.70 (Forest Stands 1a and 1b). Nonnative species cover averaged

39 percent in stand subplots, ranging from 6 percent (Field 4) to 71 percent (Forest Stand 3).

A plot of Simpson's diversity against nonnative species cover (Figure 4) revealed four

potential categories of stand risk and recovery potential, as denoted by the quadrants of the

graph: 1) stands exhibiting high native diversity and high nonnative cover (top right—Forest

Stands 1a and 3); 2) bottom right—stands exhibiting high native diversity and low nonnative

cover (Forest Stand 1b; Fields 5, 6, and 7); 3) top left—stands exhibiting low native diversity and

high nonnative cover (Forest Stand 4; Field 3); and 4) stands exhibiting low native diversity and

low nonnative cover (bottom left—Forest Stand 2; Fields 1, 2, and 4). Regression revealed

Simpson's diversity to account for 24.6 percent of the variation in nonnative cover; there was no
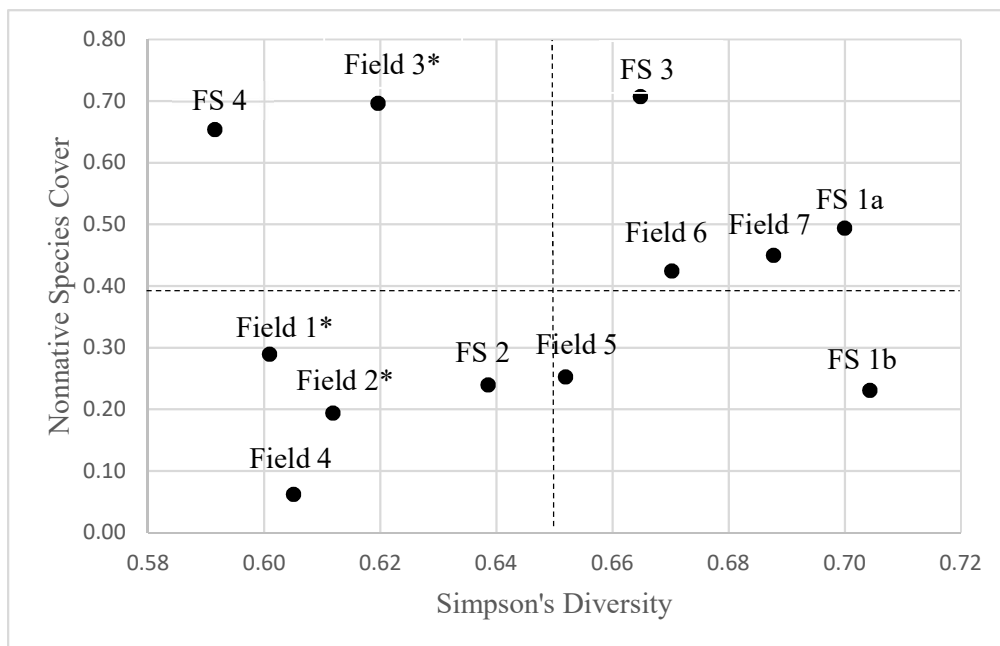
Figure 4: Stand Risk and Recovery Potential. Plotting native Simpson's diversity against nonnative species cover reveals potential categories for stand management. Dotted lines indicate the means of the two variables. Asterisks indicate stands where preserve managers sowed warm-season grasses in 2005.

evidence that this relationship was statistically significant ($F_{(1,10)}$=3.270, β=2.949, p=0.101, α=0.05).

Among forest stands (Figure 5), steeper dominance diversity curves for Forest Stands 1a and 4, where the curve rises more sharply at the extreme of the *x*-values, suggest dominance by a smaller subset of species than in the other forest stands, where the rise begins earlier on the *x*-axis and species cover is more evenly distributed. This pattern reflects the dominance of the
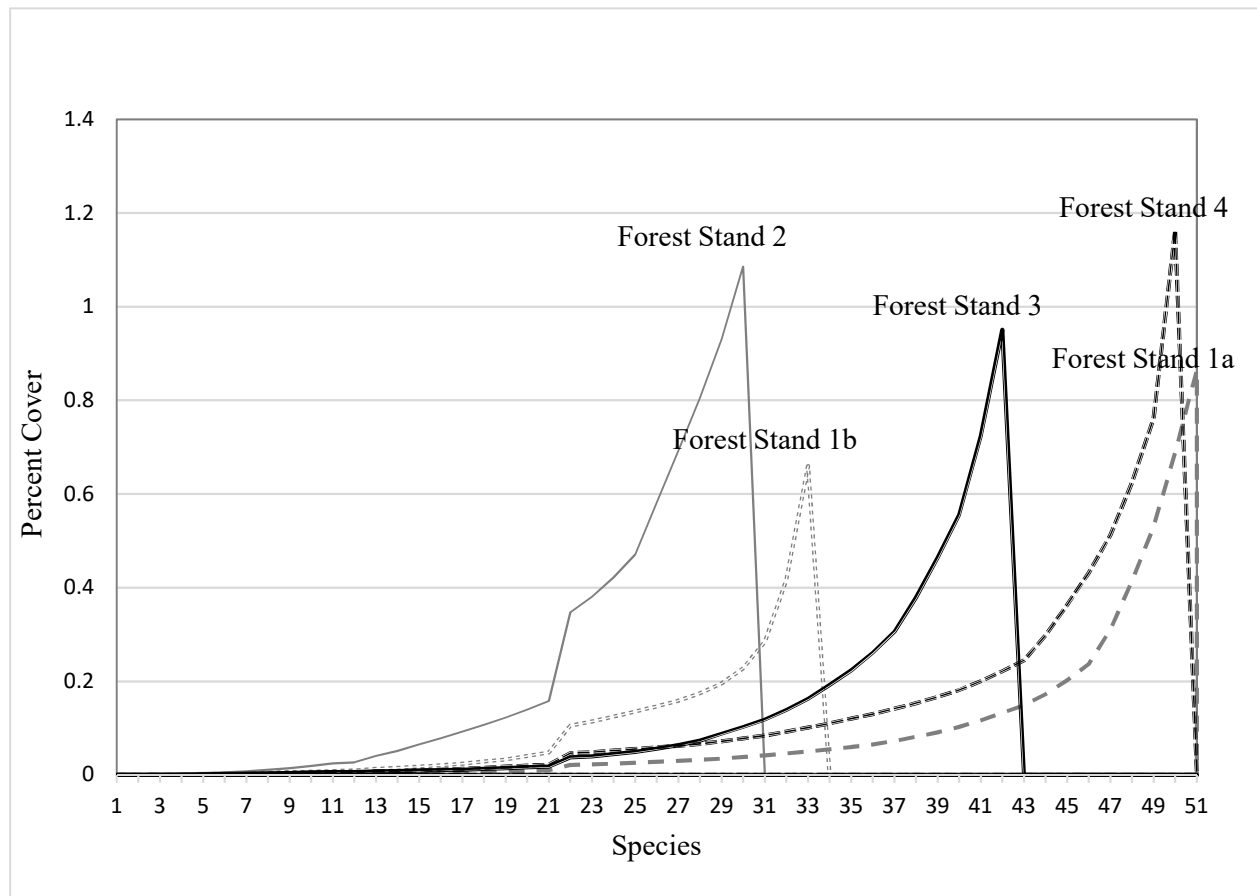
Figure 5: Dominance Diversity Curves, Forests. Stands with flatter curves indicate more evenly distributed plant species. Species composition is unique to each stand; i.e., the 31 species in Forest Stand 2 do not necessarily correspond to the first 31 species in Forest Stand 1b.
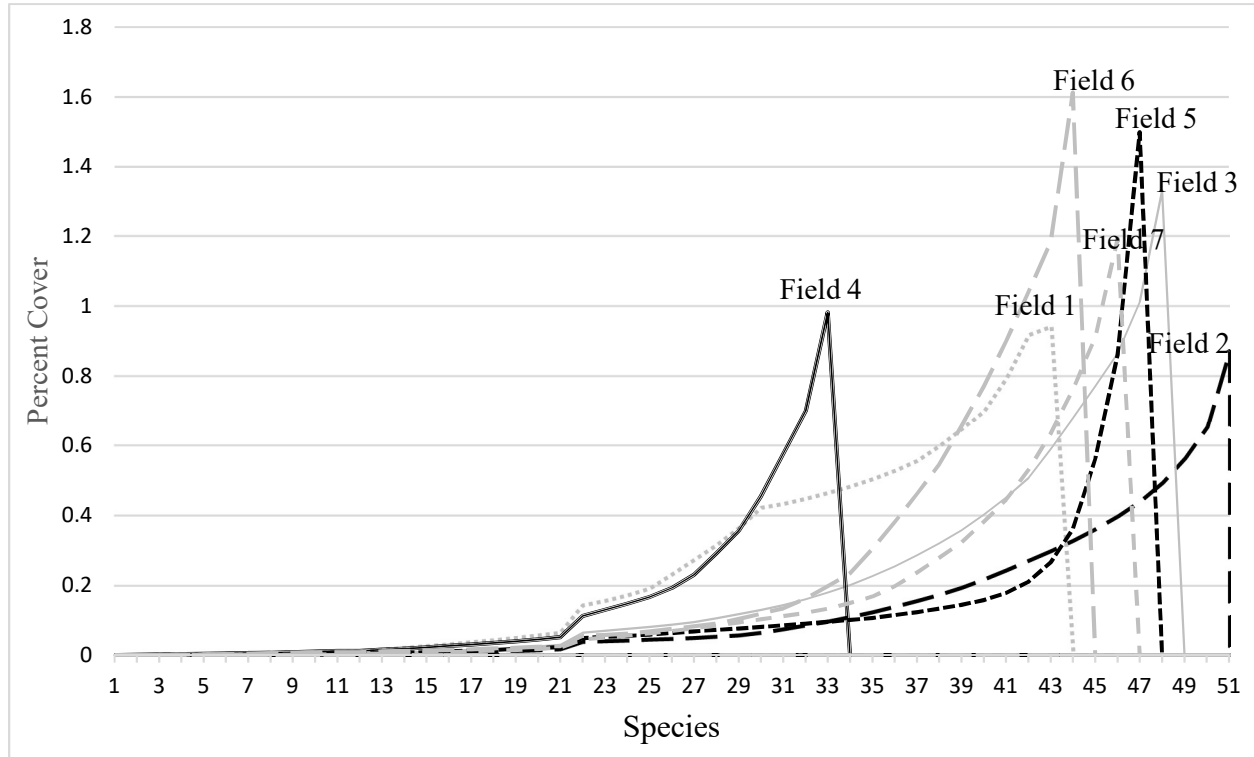
Figure 6: Dominance Diversity Curves, Fields. Stands with flatter curves, such as Field 5, indicate more evenly distributed plant species. Species composition is unique to each stand; i.e., the 34 species in Field 4 do not necessarily correspond to the first 31 species in Field 1.

nonnative *Microstegium vimineum* (Japanese stiltgrass) and *Periscaria longiseta* (oriental smartweed) in these two stands. Among fields (Figure 6), the steepest curves occurred for Field 5, likely due to the dominant presence in these fields of native *Solidago* spp. (goldenrods), which averaged 64 percent cover in this field. Most stands exhibited a somewhat steep increase at the end of the species sequence, which in most cases was accounted for by nonnative species. The nonnative species with the highest cover in each stand are presented in Table 4.

In the Jaccard matrix (Table 3), lower values indicate a higher degree of similarity between the plant community composition of two stands. As expected, the forest stands generally showed less similarity with the fields ($\bar{J}$=1.20) than with each other ($\bar{J}$=0.78) (Jaccard results were not assessed for statistical significance.) There tended to be more

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Table 3: Jaccard Matrix for Sampled Areas

	Fld 1	Fld 2	Fld 3	Fld 4	Fld 5	Fld 6	Fld 7	FS 1a	FS 1b	FS 2	FS 3	FS 4
Field 1	0.00	0.85	0.91	0.75	0.73	0.81	0.77	1.28	1.43	1.51	1.20	0.96
Field 2	0.85	0.00	0.82	0.81	0.71	0.61	0.77	1.20	1.40	1.47	1.01	0.85
Field 3	0.91	0.82	0.00	0.88	0.75	0.87	0.86	1.04	1.24	1.36	0.94	0.72
Field 4	0.75	0.81	0.88	0.00	0.84	0.81	0.72	1.23	1.39	1.48	1.09	0.93
Field 5	0.73	0.71	0.75	0.84	0.00	0.74	0.78	1.20	1.40	1.47	1.10	0.88
Field 6	0.81	0.61	0.87	0.81	0.74	0.00	0.69	1.22	1.44	1.50	1.08	0.90
Field 7	0.77	0.77	0.86	0.72	0.78	0.69	0.00	1.23	1.44	1.51	1.11	0.90
FS 1a	1.28	1.20	1.04	1.23	1.20	1.22	1.23	0.00	0.81	0.89	0.84	1.00
FS 1b	1.43	1.40	1.24	1.39	1.40	1.44	1.44	0.81	0.00	0.70	1.00	1.20
FS 2	1.51	1.47	1.36	1.48	1.47	1.50	1.51	0.89	0.70	0.00	1.06	1.31
FS 3	1.20	1.01	0.94	1.09	1.10	1.08	1.11	0.84	1.00	1.06	0.00	0.94
FS 4	0.96	0.85	0.72	0.93	0.88	0.90	0.90	1.00	1.20	1.31	0.94	0.00
Ave.	0.93	0.87	0.87	0.91	0.88	0.89	0.90	0.99	1.12	1.19	0.95	0.88

variability among the forested stands, as the within-forests Jaccard score averaged 1.03, compared to 0.89 for fields. Among fields, Fields 2 and 3 showed the most overlap with other stands ($\bar{J}$=0.87), while Field 1 showed the least overlap ($\bar{J}$=0.93). Among forests, Forest Stand 4 showed the most overlap with other stands ($\bar{J}$=0.88), while Forest Stand 2 showed the least overlap with other stands ($\bar{J}$=1.19). Forest Stand 4 generally appeared more similar to field stands ($\bar{J}$=0.69 for fields and 1.22 for forests); plant community composition in this stand resembled Field 3 the most (J=0.72) and Forest Stand 2 (J=1.31) the least. Also, although DNR delineated two sections of Forest Stand 1 (in this study, represented as 1a and 1b), the Jaccard results indicate Forest Stand 1b to be most similar to Forest Stand 2 and vice versa. This result might be expected, given that the two stands are contiguous, and managers may wish to consider them as part of one stand for management purposes and in future analyses.

Objective #2: Map spatial patterns in plant invasions.

Under a standard deviation classification, nonnative cover was found to be highest in Forest Stands 3 and 4 and Field 3 (Figure 7). Field 4 contained the least nonnative cover. Stands with higher nonnative cover typically faced invasion from *Microstegium vimineum* (Japanese stiltgrass) and one other invasive species, while stands with lower nonnative cover typically faced invasion from only one species, usually *M. vimineum*.

Of nonnative species, *M. vimineum*, *Persicaria longiseta* (oriental smartweed), and *Celastrus orbiculatus* (Oriental bittersweet) were found to be the most dominant, averaging 13.32, 5.95, and 4.00 percent, respectively, across all stands. *M. vimineum* was also the most commonly encountered species in the survey, documented in 40 of 41 plots; *C. orbiculatus* and *P. longiseta* were documented in 35 and 23 plots, respectively. In forests, *M. vimineum* was most dominant in Forest Stand 4, moderately dominant in Forest Stands 1a and 3, and negligible in Forest Stands 1b and 2. In fields, *M. vimineum* was most dominant in Field 3, moderately dominant in Field 1, and less dominant to negligible in Fields 2, 4, 5, and 6. *P. longiseta* was most invasive among forests in Forest Stand 1a and somewhat less invasive in the remaining stands. It was absent from or negligible in subplots sampled in the field stands. In forests, *C. orbiculatus* showed the highest cover in Forest Stands 3 and 1a, with lower but similar cover in the remaining stands; in fields, it was mostly negligible, with the exception of Field 6. Figure 7 depicts the percent cover of each of these species in each of the 12 stands.

After these three nonnative species, *Symphoricarpos orbiculatus* (coralberry), *Holcus lanatus* (velvet grass)*,* and *Berberis thunbergii* (Japanese barberry) were the next most dominant across stands, with an average of 3.48, 1.20, and 1.00 percent cover in sampled areas,
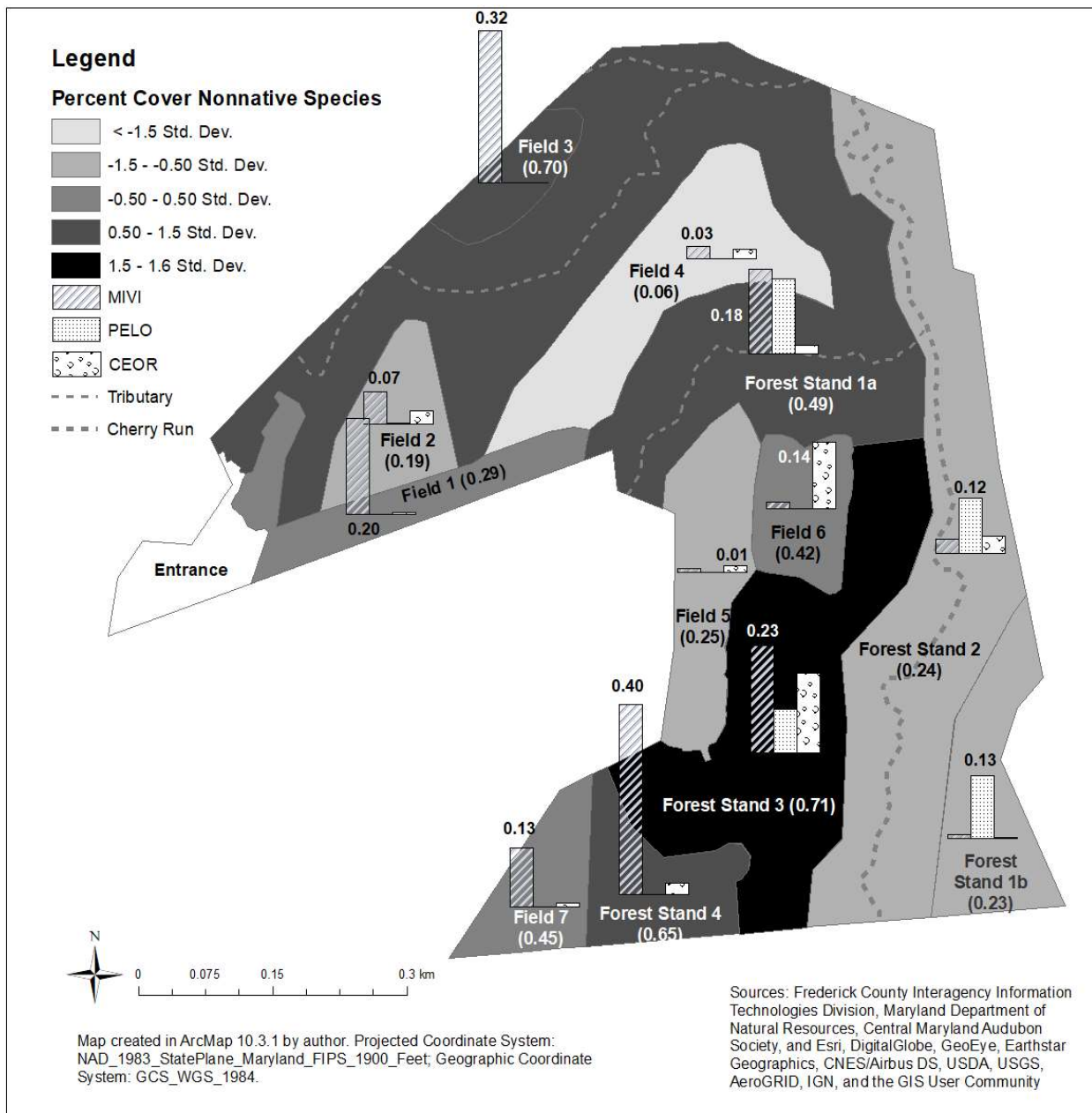
Figure 7. Habitats are shaded according to the number of standard deviations from the average nonnative cover across all habitats. The total nonnative cover for each habitat is presented in parentheses after the habitat name as a decimal figure (e.g., Forest Stand 3 = 0.71 or 71 percent nonnative cover). The average percent cover in each habitat of Microstegium vimineum *(MIVI, Japanese stiltgrass),* Persicaria longiseta *(PELO, oriental smartweed), and* Celastrus orbiculatus *(CEOR, Oriental bittersweet) are presented as bar graphs. In each habitat, the percent cover of the most dominant of the three species appears above or next to the bar for that species (e.g., MIVI = 0.40 or 40 percent in Forest Stand 4).*

respectively. Various nonnative species were found to be relatively dominant in individual stands, such as *S. orbiculatus* in Fields 3 and 6 and Forest Stands 1a and 4, *H. lanatus* in Field 5 and 7, *Lonicera japonica* (Japanese honeysuckle) in Forest Stand 1b and Field 4, *Rosa multiflora* (multiflora rose) in Forest Stand 1b, *Cirsium arvense* (Canada thistle) and *Persicaria perfoliata* (Asiatic tearthumb) in Field 1, *Potentilla indica* (Indian strawberry) in Field 2, *Glechoma hederacea* (ground ivy) in Field 3, *Hypericum perforatum* (common St. Johnswort) in Field 6, and *Kummerowia striata (*Japanese clover) in Field 7. These species are noted in Table 4.

Among native species, *Solidago* spp. (goldenrods) were most dominant at 15.02 average percent cover in sampled areas, followed by *Rubus* sp. (blackberries, 6.13 percent), *Lindera benzoin* (common spicebush, 4.32), *Panicum virgatum* (switchgrass, 2.20), *Desmodium paniculatum* (panicled tick trefoil, 2.18), *Sorghastrum nutans* (Indiangrass, 1.94), *Schizachyrium scoparium* (little bluestem, 1.84), *Apocynum cannabinum* (Indian hemp, 1.82), [1]*Andropogon gerardi* (big bluestem, 1.69), *Persicaria virginiana* (jumpseed, 1.46), *Pilea pumila* (Canadian clearweed), *Desmodium perplexum* (perplexed tick trefoil), and *Fraxinus* sp. (ash, 1.07). *Fraxinus* sp. and *Rubus* sp. were particularly common, documented in 32 and 30 plots, respectively, out of 41. In addition, *Parthenocissus quinquefolia* (Virginia creeper) and *Toxicodendron radicans* (eastern poison ivy) were among the most commonly encountered species, documented in 33 and 32 plots, though at relatively low cover.

A total of 38 unique species were documented, i.e., species occurring in only one of the 12 stands. Of these, 16 were located in Forest Stand 2, many of which were upland species often associated with oak forests, such as *Antennaria plantaginifolia* (plantain-leaved pussytoes),

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[*]These native grass species were included in the seed mix sown in three of the fields in 2006.

Chimaphila maculata (striped wintergreen), *Galearis spectabilis* (showy orchid), *Hieracium venosum* (rattlesnake weed), *Houstonia longifolia* (long-leaved bluet), *Packera tomentosa* (woolly ragwort), *Rhododendron periclymenoides* (pinxter flower), and *Vaccinium pallidum* (early lowbush blueberry).

Objective #3: Produce a checklist of vascular plants and ferns.

The species checklist is presented in Appendix 1.

DISCUSSION

The purpose of the diversity measures calculated here is not to serve as the sole indicator of the area's ecological health or wildlife value. At local scales, maintenance of or increase in species richness can mask partial or complete reorganization of species composition (Blowes et al. 2019). Many studies suggest that local and regional biodiversity can persist or even increase in invaded areas (Vellend 2017), which might otherwise be considered ecologically degraded. According to the intermediate disturbance hypothesis, species diversity of invaded communities may increase in initial stages of succession due to addition of invasives, then plateau and eventually decrease as native species diversity declines (Catford et al. 2011). Several results from this study indicate that portions of the preserve may be undergoing a disturbance succession whereby nonnative species are ascending in importance. For example, in some stands, such as Field 3 and Forest Stand 4, high overall diversity in sampled areas was accompanied by high nonnative cover, a relationship consistent with the intermediate disturbance hypothesis. In addition, the average overall plant diversity across sampled areas was higher than the average native plant diversity, a finding also consistent with the intermediate disturbance hypothesis (although this comparison not analyzed for statistical significance).

Conversely, low vegetative diversity is not always indicative of poor ecological health; single species in genera such as *Quercus* (oaks) and *Prunus* (cherry) (Tallamy and Schropshire 2009) and *Asclepias* (milkweed) (Agrawal 2005) can support complex communities of vertebrate and invertebrate organisms. In this study, while lower native diversity in Field 3 may be explained by the high degree of nonnative cover, lower native diversity in Fields 1, 2, and 4 is likely due to the dominant presence of a few highly beneficial and competitive native species.

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These include *Solidago* spp. (goldenrods), a vital source of late-season nectar and pollen to many insects, and warm-season grasses such as *Andropogon gerardi* (big bluestem), *Schizachyrium scoparium var. scoparium* (little bluestem), *Sorghastrum nutans* (Indiangrass), and *Andropogon virginicus var. virginicus* (broomsedge bluestem). These grasses, which were sown in Fields 1, 2, and 3 in 2005, grow 2+ m in height and provide nesting and brooding cover, travel corridors, and winter food and cover for birds and other wildlife. In field subplots, the four species of warm-season grasses averaged 10.62 percent cover, while *Solidago* spp. averaged 6.15 percent cover.

Combinations of diversity measures reveal a potential schema for classifying stands into management regimes. As discussed in the Results, stands can be classified into four categories corresponding to the four quadrants of the Invasion Risk and Recovery Potential graph (Figure 4). Stands exhibiting high native diversity and low nonnative cover (bottom right quadrant) should be monitored regularly for signs of increased invasion, with spot treatment of locally invaded patches, but they can be a considered a low priority for comprehensive management; Forest Stand 2 should be monitored especially closely and frequently, due to its unique composition and location. In stands exhibiting high native diversity and high nonnative cover (top right quadrant), invasives removal will be an extensive undertaking, but recovery should be favored by propagule pressure from the hypothetically substantial native seed bank. In stands exhibiting low native diversity and high nonnative cover (top left quadrant), invasive species removal will be a large and more expensive undertaking, as it will likely require supplemental plantings of native species in order to ensure sufficient propagule pressure for recovery. Finally, stands exhibiting low native diversity and low nonnative cover (bottom left quadrant) should be monitored closely as they present a substantial risk of invasion, given low competitive pressure

from natives; early detection and rapid response protocols may prove effective in these stands.

Descriptions of diversity and uniqueness for each stand are presented in Table 4, with stands

grouped according to the management recommendations described in the schema above.

Table 4: Habitat Summaries and Management Recommendations

	Description	Nonnative Species to Watch for
Monitor		
Forest Stand 2	A rich and highly distinct habitat with low native diversity (perhaps due to larger amounts of bare ground/coarse woody debris); low degree of nonnative cover; high priority for monitoring due to presence of unique native species and proximity to future development	PELO, CEOR, MIVI; OPUN*
Field 1	A more distinct habitat with some degree of native diversity and low nonnative cover	MIVI, PELO, SYMP; ARHI*
Field 2	A rich but less distinct habitat with some degree of native diversity and low nonnative cover	MIVI, CEOR, POIN
Field 4	A more distinct habitat with some degree of native diversity and very low nonnative cover	MIVI, CEOR, LECU
Field 5	A less distinct habitat dominated by SOLI, with some degree of native diversity and low nonnative cover	HOLA, CEOR, MIVI
Field 6	A less distinct habitat with a fair degree of native diversity and some amount of nonnative cover, on the cusp of the need for intervention	CEOR, SYMP, HYPE
Remove and Monitor		
Forest Stand 1a	A more distinct habitat with high native richness and diversity and a more even distribution of species, but suffering from some amount of nonnative cover	MIVI, PELO, SYMP
Forest Stand 1b	A less distinct habitat with some native richness and diversity; high degree of nonnative cover	PELO, LOJA, ROMU
Forest Stand 3	A more distinct habitat with some native diversity; high degree of nonnative cover	MIVI, CEOR, PELO

Remove, Plant, and Monitor		
Forest Stand 4	A rich but less distinct habitat more similar in composition to fields, reflecting successional state; some degree of native diversity and high degree of nonnative cover, including a very high density of MIVI	MIVI, PELO, SYMP
Field 3	A rich but less distinct habitat similar in composition to FS4, with low native diversity and a high degree of nonnative cover, including a very high density of MIVI	MIVI, PELO, LECU

*Species abbreviations are as follows: CEOR = Celastrus orbiculatus (Oriental bittersweet);CIAR = Cirsium arvense (Canada thistle); GLHE = Glechoma hederacea (ground ivy); HOLA = Holcus lanatus (common velvetgrass); HYPE = Hypericum perforatum (common St. Johnswort); KUST = Kummerowia striata (Japanese clover); LOJA = Lonicera japonica (Japanese honeysuckle); MIVI = Microstegium vimineum (Japanese stiltgrass); PELO = Persicaria longiseta (oriental smartweed); PEPE = Persicaria perfoliata (Asiatic tearthumb); POIN = Potentilla indica (Indian strawberry); ROMU = Rosa multiflora (multiflora rose); SOLI = Solidago sp. (goldenrods); SYOR = Symphoricarpos orbiculatus (coralberry); WSG = warm-season grasses. *OPUN = Oplismenus undulatifolius (wavyleaf basketgrass), a species subject to an Early Detection Rapid Response protocol in Maryland and detected in two plots in this stand. **ARHI = Arthraxon hispidus (small carpgrass), a species detected only in minute quantities in plots but encroaching at high densities on the nonsampled edge of this field.*

The degree of plant invasion varied throughout the preserve (Figure 7). The fields showed significantly less total nonnative cover (M=0.34, SD=0.28) than the forests (M=0.56, SD=0.27) (df=39, t=-2.523, p=0.016, α=0.05). This may be due to the superior competitive abilities of the warm-season grasses and goldenrods in the fields. In the forested plots, some of the nonnative species documented have persisted at least as far back as a 2002 DNR survey (Seipp et al. 2002). The forested plots were particularly susceptible to three species native to the Asian continent that have managed to persist and even thrive in shady habitats: *Microstegium vimineum* (Japanese stiltgrass), *Persicaria longiseta* (oriental smartweed), and *Celastrus orbiculatus* (Oriental bittersweet). Of the three, *C. orbiculatus* presents the most substantial concern. While *M. vimineum* is a prolific invader of Northeastern habitat types and has

frequently been documented strongly outperforming native competitors (Bauer and Flory 2011, Leicht et al. 2005)*,* more research is needed into its impacts on invertebrate communities; one study found that invertebrate taxa were more abundant in stiltgrass patches, and diversity, richness, and abundance of spiders was also higher in these patches (Landsman 2019). *C. orbiculatus* can suppress native trees in invaded forests (Delile and Parshall 2018) and was particularly problematic in Forest Stands 1 and 3, where thick growth on the forest floor impeded access and vines spiraled into the canopy, with new vines twining around old vines. These conditions could impede the stands from maturing into an older-growth association (Durcho 2018).

Invasion was highest in Forest Stands 3 and 4, perhaps due to the more recent abandonment and the successional nature of these stands. However, Forest Stand 1a, despite being the most mature of the stands, showed a medium degree of nonnative cover. The second oldest stand, Forest Stand 2, along with the similar Forest Stand 1b, contained the least amount of nonnative cover, suggesting characteristics that confer a degree of resistance to invasion. This conclusion is borne out by the stand's high Jaccard score and high number of unique species, including riparian species and higher-elevation species, found on the upland slopes and characteristic of oak forests in the region. Native plants in an intact forest can prevent establishment of nonnative species if they occupy nearly all bare ground or intercept nearly all light at ground level, as long as they are protected from disturbance, which can remove native competitors and supply nutrients to invaders (Green et al. 2004, Simberloff et al. 2012). From this perspective, the adjacent stands may be serving as a buffer to protect this stand from invasion, at least for the time being.

As Forest Stand 2 is located adjacent to highly invaded stands, and also will be located adjacent to the largest of three planned developments, regular and frequent monitoring is critical to preserve the native biodiversity within this stand. In particular, Cherry Run should be viewed as a potential vector of invasive species. The two records of *Oplismenus undulatifolius* (wavyleaf basketgrass), an emerging invasive species in Maryland, were documented within the visible water mark of the stream bank, suggesting the creek may be a viable vector for at least some species, perhaps by serving as a water source for animals that carry the seeds on their fur.

The persistence of numerous native species, such as those listed on pp. 23-24, suggests the potential for recovery and the continued importance of the plant communities to native wildlife. For example, *Desmodium paniculatum* (panicledleaf tick-trefoil), a frequent component of the fields, provides pollen to long-tongued bees; foliage to several lepidoptera larvae, many beetles and other insects, and mammals; and seeds to upland gamebirds and small rodents; a member of the Fabaceae, it enriches the nitrogen content of soil (Kirk and Belt 2009). *Parthenocissus quinquefolia* (Virginia creeper), a small component of the majority of stands, provides cover for a number of faunal species, with songbirds, gamebirds, and mammals consuming the berries (Bush 2002). Gamebirds, songbirds, and mammals also consume the seeds of *Fraxinus americana* (white ash), while mammals consume the bark and cavity nesters use the tree for habitat (Nesom 2000). Although the invasive *Agrilus planipennis* (emerald ash borer) has decimated many mature ash trees throughout the preserve, seedlings were frequently encountered throughout plots, suggesting the potential for recovery of the species should *A. planipennis* populations be brought under control.

A Note about the Functions of Baseline Data

The results gathered in the current study will establish a baseline against which post-development data can be compared to see whether patterns of diversity and invasion are changing. For example, even if development does not decrease overall plant richness, native plant species richness could decline, indicating that the area is becoming more populated with invasive species, or species evenness could decline, indicating that a single species or group of species is becoming more dominant.

Increased overlap between plant community compositions in future study could indicate the area is undergoing biotic impoverishment or homogenization, defined as a reduction in spatial diversity due to the replacement of unique endemic species with widespread nonindigenous species (McKinney and Lockwood 1999) (but see Vellend et al. 2007; in recent farm fields, homogenization may be caused by dispersal filters that limit the pool of colonizing species, rather than invasive species per se). Increased overlap also could be accompanied by the loss of rare plant communities or locally rare species, and by decreasing genetic diversity it can hinder plant communities from adapting to change (Eriksson and Hillebrand 2019).

Finally, if the preserve is resampled after the new developments are in place, the baseline maps can be redrawn to assess whether plant invasions are intensifying or spreading further throughout the area.

CONCLUSION

The results gathered in the current study indicate that a small number of nonnative species are encroaching on certain plant communities within the Fred J. Archibald Audubon

Sanctuary. Although nonnative cover is high in some areas, pockets of native biodiversity persist, suggesting the potential for recovery as well as the continued value of these plant communities to native fauna. Management of invasive plant species is critical to maintaining the wildlife value of the nature preserve, and results of diversity and composition analyses suggest a possible schema of management strategies, ranging from low to intensive levels of management.

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APPENDIX 1: CHECKLIST OF VASCULAR PLANTS AND FERNS

The following checklist presents the 202 identifiable species from 69 families documented during the study. Where individuals were identified with reasonable, but not absolute, certainty (typically due to small size or the absence of distinguishing features such as inflorescences or fruits), the notation *cf* is presented. Family names are presented in bold, common names are listed in parentheses, the frequency of each species, or number of plots out of 41 in which it was documented, is presented at the end of each listing, and species nonnative to Maryland are indicated with an asterisk. This list is not intended to be exhaustive but will provide the basis for continuing study.

Photograph records of many of the species documented during the study are available on iNaturalist at https://bit.ly/2OJEPTX.

Acanthaceae
Ruellia caroliniensis (Walter) Steudel (Carolina wild petunia) 1
Aceraceae
Acer sp. (seedlings) (maple) 11
Acer negundo Linnaeus (box elder) 7
Acer rubrum Linnaeus (red maple) 2
Adoxaceae
Viburnum prunifolium Linnaeus (blackhaw) 3
Amaryllidaceae
*Allium vineale Linnaeus (wild garlic, field-garlic) 17
Anacardiaceae
Toxicodendron radicans (Linnaeus) Kuntz (eastern poison ivy) 32
Apiaceae
Cryptotaenia canadensis (Linnaeus) De Candolle (Canadian honewort) 2
*Daucus carota Linnaeus (Queen Anne's lace, wild carrot) 11
Sanicula sp. (snakeroot) 11
Apocynaceae
Apocynum cannabinum Linnaeus (Indian hemp) 25
Asclepias incarnata Linnaeus (swamp milkweed) 2
Asclepias syriaca Linnaeus (common milkweed) 19

Asclepias viridiflora Rafinesque (green milkweed, short green milkweed) 2
Araceae
Arisaema triphyllum (Linnaeus) Schott (common jack in the pulpit) 14
Asparagaceae
cf *Maianthemum racemosum* (Linnaeus) Link (false Solomon's-seal) 1
Polygonatum biflorum (Walter) Elliott var. biflorum (smooth Solomon's-seal, small Solomon's seal) 1
Aspleniaceae
Asplenium platyneuron (Linnaeus) Britton, Sterns, & Poggenburg (ebony spleenwort) 4
Asteraceae
Achillea borealis Linnaeus (American yarrow) 9
Ambrosia artemisiifolia Linnaeus (annual ragweed, common ragweed) 16
Antennaria plantaginifolia (Linnaeus) Richardson (plantain-leaved pussytoes, woman's pussytoes) 1
*cf Carduus acanthoides Linnaeus (spiny plumeless thistle) 1
Cirsium altissimum (Linnaeus) Sprengel (tall thistle) 8
*Cirsium arvense (Linnaeus) Scopoli (Canada thistle, creeping thistle) 10

Cirsium discolor (Muhlenberg) Sprengel (field thistle) 16

Conoclinium coelestinum (Linnaeus) De Candolle (blue mistflower, blue boneset) 3

Erigeron strigosus Muhlenberg var. strigosus (prairie fleabane, daisy fleabane) 17

Euthamia graminifolia (Linnaeus) Greene (flat-topped goldenrod, flat-top fragrant goldenrod) 14

Hieracium venosum Linnaeus (rattlesnake weed, rattlensake hawkweed) 1

Nabalus sp. (rattlesnake root) 3

Packera tomentosa (Michaux) C. Jeffrey (woolly ragwort) 1

Solidago sp. (goldenrod) 23

cf *Symphyotrichum cordifolium* (Linnaeus) Nesom (common blue wood aster) 1

cf *Symphyotrichum laeve* (Linnaeus) A. & D. Love (smooth blue aster) 1

cf *Symphyotrichum lateriflorum* (Linnaeus) A. & D. Love (Calico aster) 3

Symphyotrichum pilosum (Willdenow) Nesom (hairy white old field aster) 11

Taraxacum officinale Wiggers *subsp. officinale* (common dandelion) 1

Verbesina alternifolia (Linnaeus) Britton ex Kearney (wingstem) 12

Vernonia sp. (nonflowering) (ironweed) 3

Vernonia gigantea (Walter) Trelease ex Branner & Coville (giant ironweed) 2

Vernonia noveboracensis (Linnaeus) Michaux (New York ironweed) 6

Athyriaceae
Athyrium sp. Roth ex Mertens (ladyfern) 1

Balsaminaceae
Impatiens sp. (jewelweed) 2

Berberidaceae
Berberis thunbergii de Candolle (Japanese barberry) 14

Podophyllum peltatum Linnaeus (mayapple) 2

Betulaceae
Carpinus caroliniana Walter (American hornbeam, ironwood) 5

Ostrya virginiana (P. Miller) K. Koch (hophornbeam, eastern hophornbeam) 4

Bignoniaceae
Campsis radicans (Linnaeus) Seeman (trumpet creeper) 2

Boraginaceae
Hackelia virginiana (Linnaeus) I.M. Johnston (beggarslice) 13

*cf *Myosotis scorpioides* Lamarck (true forget-me-not) 1

Brassicaceae
Alliaria petiolata (Bieberstein) Cavara & Grande (garlic mustard) 18

Brassicaceae
cf *Lepidium virginicum* Linnaeus (Virginia pepperweed, wild pepperweed) 1

Campanulaceae
Lobelia inflata Linnaeus (Indian-tobacco) 14

Cannabaceae
Celtis occidentalis Linnaeus (common hackberry, northern hackberry) 8

Caprifoliaceae
Dipsacus fullonum Linnaeus (Fuller's teasel) 1

Lonicera japonica Thunberg (Japanese honeysuckle) 30

Lonicera maackii (Ruprecht) Maximowicz (Amur honeysuckle) 1

Lonicera morrowii Gray (Morrow's honeysuckle) 2

Symphoricarpos orbiculatus Moench (coralberry) 27

Caryophyllaceae
Dianthus armeria Linnaeus (Deptford pink) 3

Celastraceae
Celastrus orbiculatus Thunberg (Oriental bittersweet, Chinese bittersweet) 35

Commelinaceae
Commelina communis Linnaeus (Asiatic dayflower) 1

Convolvulaceae
Calystegia sepium (Linnaeus) R. Brown (hedge false bindweed) 2

Cornaceae
Cornus florida (flowering dogwood) 6

Cupressaceae
Juniperus virginiana Linnaeus *var. virginiana* (Eastern red cedar) 5

Cyperaceae
cf *Carex blanda* Dewey (Eastern woodland sedge) 10

Carex frankii Kunth (Frank's sedge) 6

Carex platyphylla Carey (broad-leaved sedge) 1

Carex radiata (Wahlenberg) Small (eastern star sedge) 2

Cyperus esculentus Linnaeus *var. leptostachyus* Boeckler (yellow nut sedge) 1

Cyperus rotundus Linnaeus (nutgrass) 2

Scirpus sp. (bulrush) 1

cf *Scleria* sp. (nutrush) 1

Dryopteridaceae

Polystichum acrostichoides (Michaux) Schott (Christmas fern) 7

Ebenaceae

Diospyros virginiana Linnaeus (common persimmon) 10

Eleagnaceae

Elaeagnus umbellata Thunberg (autumn olive) 18

Ericaceae

Chimaphila maculata (Linnaeus) Pursh (spotted wintergreen, striped prince's pine) 1

Rhododendron periclymenoides (Michaux) Shinners (pinxter flower, pinxter azalea) 1

Vaccinium pallidum Aiton (early lowbush blueberry, hillside blueberry) 1

Euphorbiaceae

Acalypha rhomboidea Rafinesque (common three-seeded mercury) 6

Fabaceae

Amphicarpaea bracteata (Linnaeus) Fernald (American hog peanut) 8

Cercis canadensis Linnaeus (eastern redbud) 3

Chamaecrista fasciculata (Michaux) Greene *var. fasciculata* (partridge pea) 1

Desmodium paniculatum (Linnaeus) De Candolle *var. paniculatum* (panicledleaf tick-trefoil, panicled tick-trefoil) 25

Desmodium perplexum Schubert (perplexed ticktrefoil) 21

Gleditsia triacanthos Linnaeus (honeylocust, thorny locust) 5

cf *Glycine* sp. (soybean) 1

*Kummerowia striata (Thunberg) Schindler (Japanese clover) 12

*Lespedeza cuneata (Dumont) G. Don (Sericea lespedeza) 13

*Lotus corniculatus Linnaeus (bird's foot trefoil) 0

Robinia pseudoacacia Linnaeus (black locust) 6

*cf *Securigera varia* (Linnaeus) Lassen (crownvetch) 1

Trifolium dubium Sibthorp (suckling clover) 11

Trifolium pratense Linnaeus (red clover) 2

Trifolium repens Linnaeus (white clover) 7

Fagaceae

Fagus grandifolia Ehrhart (American beech) 5

Quercus alba Linnaeus (white oak) 3

Quercus montana (chestnut oak) 1

Quercus rubra Linnaeus (northern red oak) 4

Quercus velutina Lamarck (black oak) 3

Geraniaceae

Geranium maculatum Linnaeus (wild geranium, spotted geranium) 1

Hypericaceae

**Hypericum perforatum* Linnaeus (common St. Johnswort) 2

Hypericum punctatum Lamarck (spotted St. Johnswort) 4

Juglandaceae

Carya sp. (seedlings) (hickory) 2

Carya cordiformis (Wangenheim) K. Koch (bitternut hickory) 6

Carya glabra (P. Miller) Sweet (pignut hickory) 6

Carya ovata (P. Miller) K. Koch (shagbark hickory) 2

Carya tomentosa (Lamarck) Nuttall (mockernut hickory) 4

Juglans nigra Linnaeus (black walnut) 16

Juncaceae

Juncus effusus Linnaeus *subsp. solutus* (Fernald & Wiegand) Hamet-Ahti (soft rush, common rush) 1

Juncus secundus Beauvois ex Poiret (lopsided rush) 2

Juncus tenuis Willdenow (poverty rush, path rush) 12

Luzula acuminata Rafinesque (hairy woodrush) 1

Lamiaceae

Clinopodium vulgare Linnaeus (wild basil) 14

Collinsonia canadensis Linnaeus (richweed, northern horse-balm) 1

**Glechoma hederacea* Linnaeus (ground ivy, gill-over-the-ground) 3

**Perilla frutescens* (Linnaeus) Britton (beefsteak plant) 3

Prunella vulgaris Linnaeus (common selfheal, heal-all) 1

Lauraceae
Lindera benzoin (Linnaeus) Blume (common spicebush, spicebush) 16
Sassafras albidum (Nuttall) Nees (sassafras) 1

Magnoliaceae
Liriodendron tulipifera Linnaeus (tulip poplar, tuliptree) 13

Moraceae
Morus alba Linnaeus (white mulberry) 6

Nyssacae
Nyssa sylvatica Marshall (black gum, black tupelo) 1

Oleaceae
Fraxinus sp. (ash) 32

Onagraceae
Circaea canadensis (Linnaeus) Hill *subsp. canadensis* (broad-leaved enchanter's nightshade) 11
Oenothera biennis Linnaeus (common evening primrose) 1

Ophioglossaceae
Botrypus virginianus (Linnaeus) Michaux (rattlesnake fern) 8
cf *Sceptridium dissectum* (Sprengel) Lyon (cutleaf grapefern, cut-leaved grapefern) 2

Orchidaceae
Galearis spectabilis (Linnaeus) Rafinesque (showy orchid) 1

Oxalidaceae
Oxalis stricta Linnaeus (common yellow woodsorrel) 19

Papaveraceae
Sanguinaria canadensis Linnaeus (bloodroot) 2

Phrymaceae
Phryma leptostachya Linnaeus (American lopseed) 1

Phytolaccaceae
Phytolacca americana Linnaeus (American pokeweed) 2

Plantaginaceae
cf *Plantago* sp. (plantain) 1
Plantago major Linnaeus (common plantain, broadleaf plantain) 1

Plantanaceae
Platanus occidentalis Linnaeus (American sycamore) 8

Poaceae
Andropogon gerardi Vitman (big bluestem) 12
Andropogon virginicus var. virginicus (broomsedge bluestem) 9
Arthraxon hispidus (Thunberg) Makino (small carpgrass, small carpetgrass) 5
Bromus commutatus Schrader (meadow brome, hairy cress) 18
Dactylis glomerata Linnaeus (orchardgrass) 8
Dicanthelium boscii (Poiret) Gould & C.A. Clark (Bosc's panicgrass) 1
Dichanthelium clandestinum (Linnaeus) Gould (deertongue, deer-tongue grass) 11
Elymus glabriflorus (southeastern wildrye) 1
Elymus hystrix Linnaeus (Eastern bottlebrush grass) 9
Elymus macgregorii R. Brooks & J.J.N. Campbell (early wildrye) 2
Elymus virginicus Linnaeus (Virginia wildrye) 3
Holcus lanatus Linnaeus (common velvetgrass) 14
Leersia virginica Willdenow (white grass) 9
Microstegium vimineum (Trinus) A. Camus (Japanese stiltgrass) 40
Lolium arundinaceum (Schraber) Darbyshire (tall fescue) 9
Muhlenbergia schreberi J.F. Gmelin (nimblewill) 3
Oplismenus undulatifolius (Arduino) Beauvois (wavyleaf basketgrass) 2
Panicum virgatum Linnaeus (switchgrass) 18
Phleum pratense Linnaeus (timothy) 6
Poa pratensis Linnaeus *subsp. pratensis* (Kentucky bluegrass) 17
Schizachyrium scoparium (Michaux) Nash *var. scoparium* (little bluestem) 15
Sorghastrum nutans (Linnaeus) Nash (Indiangrass) 10
Sorghum halepense (Linnaeus) Persoon (Johnsongrass) 3
Sphenopholis intermedia (Rydberg) Rydberg (slender wedgescale) 2
Tridens flavus (Linnaeus) Hitchcock (purpletop tridens, purple top) 10

Polygonaceae
cf *Persicaria amphibia* (Linnaeus) S.F. Gray (water knotweed) 3

Persicaria longiseta (de Bruyn) Moldenke (oriental smartweed, oriental lady's thumb) 23
Persicaria maculosa S.F. Gray (spotted ladysthumb) 1
Persicaria perfoliata (Linnaeus) H. Gross (Asiatic tearthumb, mile-a-minute weed) 6
Persicaria virginiana (Linnaeus) Gaertner (jumpseed) 15
Rumex crispus Linnaeus (curly dock) 1
Ranunculaceae
Actaea racemosa Linnaeus (black baneberry, black cohosh) 1
cf *Clematis virginiana* Linnaeus (devil's darning needles, Virgin's bower) 1
Rosaceae
Agrimonia gryposepala Wallroth (tall hairy agrimony) 4
cf *Crataegus* sp. (hawthorn) 1
Geum canadense Jacquin (white avens) 23
*cf *Geum urbanum* (wood avens) 10
Potentilla canadensis var. canadensis (dwarf cinquefoil) 1
**Potentilla indica* (Andrews) Wolf (Indian strawberry) 15
Potentilla simplex Michaux (common cinquefoil) 1
Prunus serotina Ehrhart (black cherry) 15
**Pyrus calleryana* Decaisne (Callery pear) 2
**Rosa multiflora* Thunberg (multiflora rose) 29
Rubus occidentalis Linnaeus (black raspberry) 4
**Rubus phoenicolasius* Maximowicz (wineberry) 16
Rubus sp. (blackberry) 30
Rubiaceae
Galium asprellum Michaux (rough bedstraw) 1

Galium circaezans Michaux (licorice bedstraw) 6
Galium pilosum Aiton (hairy bedstraw) 7
Galium triflorum Michaux (fragrant bedstraw, sweet-scented bedstraw) 7
Houstonia longifolia Gaetner *var. compacta* Terrell (long-leaved bluet) 1
Scrophulariaceae
**Verbascum thapsus* Linnaeus (common mullein) 1
Simaroubaceae
**Ailanthus altissima* (tree of heaven) 10
Solanaceae
Physalis heterophylla Nees (clammy groundcherry) 3
Solanum carolinense Linnaeus (Carolina horsenettle) 20
Ulmaceae
Ulmus sp. (elm) 17
Urticaceae
Parietaria pensylvanica Muhlenberg ex Willdenow (Pennsylvania pellitory) 1
Pilea pumila (Linnaeus) Gray (Canadian clearweed) 16
Verbenaceae
Verbena urticifolia Linnaeus (white vervain) 15
Violaceae
Viola sp. (violet) 19
Vitaceae
**Ampelopsis glandulosa* (Wallich) Momiyama (porcelain berry, Amur peppervine) 19
Parthenocissus quinquefolia (Linnaeus) Planchon (Virginia creeper) 33
Vitis sp. (grape)