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Identification and Control of Invasive Plant Species

1999 Annual Report

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The purpose of this research was to: (1) identify all vascular plant species present in the North Woodlot of the Fernald Environmental Management Project, (2) assess which species were non-indigenous and to evaluate their threat via relative abundance, (3) conduct a literature search for control methods, and (4) implement a 3-year experimental study on species control.

The design of this research called for a four-year timeline with two major phases. Phase-I (Objectives 1 and 2) was to be completed in the first year (1998) and was directed primarily at the identification and assessment of invasive species along with site reconnaissance and refinement of experimental plans for Phase-II (1999-2001). Phase-II (Objectives 3 and 4) was to begin in the second year and continue through the end of the fourth year.

The 1998 Annual Report (McCarthy 1998) provided the baseline information regarding Phase-I with an overview of the major habitats, soils, and vegetation-environment relationships on the North Woodlot. I considered it prudent to continue the floristic survey for a second field season and provide an update on the flora and final list of vascular plant species encountered over the 2-year period. However, most of the effort during 1999 consisted of initiating Phase-II and establishing the primary field experiment to study the control and ecological effects of Amur honeysuckle.

METHODS, PROGRESS, and RESULTS

Floristic Analysis: Final Report

The floristic analysis is now complete as of the writing of this annual report. The author and Ohio University doctoral student Darrin L. Rubino visited the study area for 2-day periods on April 9, June 3, July 8, and August 16, 1999. Because of administrative reasons, the project began late in 1998, so we were particularly concerned with re-examining the vegetation for spring ephemerals. During each field visit in 1998 and 1999, we systematically walked most of the study area. We made every effort to cover all major habitat types in as many geographic areas as possible. A voucher specimen was collected for every plant identified. Most identifications were made in the field with fresh material. All specimens were pressed, dried, mounted, and deposited as vouchers in the Bartley Herbarium of Ohio University.

As in the previous year, for each species encountered, we coded its presence to as many of the five previously defined habitats as applicable. We also used a relative abundance scale (Palmer et. al. 1995) to rate the relative abundance of each species (1 = rare to 5 = abundant). The abundance rating is provided for the entire study area and was not sub-divided by habitat. See McCarthy (1998) for a full description of the habitats and abundance scores. The habitat and abundance ratings are important because they provide considerable additional ecological information that may be useful for environmental management decisions. A non-indigenous plant with an abundance of 1 is ecologically very different than one with a rating of 5, yet both just show up as a single line entry on a flora.

Taxonomic nomenclature for this investigation follows Gleason and Cronquist (1991) along with the companion manual (Holmgren 1998). The scope of the investigation was limited to vascular plant species. Thus, we limited ourselves to the Divisions Lycopodiophyta (lycopods), Equisetophyta (horsetails), Polypodiophyta (ferns & allies), Pinophyta (pines), and Magnoliophyta (flowering plants). The Ohio flora volumes were used as a secondary reference source (because it is not yet complete) and included Braun (1961), Braun (1967), Fisher (1988), and Cooperrider (1995). Gleason and Cronquist (1991) was also used to determine native ranges and to classify a species as indigenous or non-indigenous.

The primary product of a flora is the checklist and associated summary statistics (Table 1). At the end of this study, we discovered a total of 332 taxa (282 in 1998, 50 in 1999) in 203 genera and 75 families. "Taxa" are used in place of "species" because we occasionally have more than one varietal form of the same species or have a hybrid. The two largest families were the aster family (Asteraceae, 45 taxa) and the grass family (Poaceae, 42). Moderately large families (i.e., $\geq$ 10 taxa) included the following: rose (Rosaceae, 22), sedge (Cyperaceae, 18), mustard (Brassicaceae, 15), bean (Fabaceae, 12), and smartweed (Polygonaceae, 12). Most of these families tend to be herbaceous in nature.

Of the 332 taxa, 30.5 percent are non-indigenous. A proportion this high is virtually unheard of for a natural area; however, not particularly unusual for areas that have a history of heavy anthropogenic disturbance, motorized vehicle traffic, and cattle grazing. Most local floras, with "moderate" disturbance regimes, usually contain 20 percent non-indigenous species. The proportion of non-indigenous species varies greatly among families. The mustards have 74 percent non-indigenous taxa, grasses 43 percent, asters 29 percent, and sedges 0 percent. The highest proportions of non-indigenous species are located in the most heavily grazed meadow and trail areas. Removal of grazing animals and restricting motorized

vehicles to the gravel road should reduce this proportion over time. Trail mowing should be discouraged and habitats should be left undisturbed to proceed as naturally through succession as possible.
Of the non-natives, only several might be considered "invasive," although a number are problematic. Amur honeysuckle is certainly a major pest species at this site and has dramatically influenced the understory of several stands of young thicket forest. Multiflora rose (*Rosa multiflora*) is problematic in the old-fields. Garlic mustard (*Alliaria petiolata*) has come in thickly (in patches) on the southern areas of the mature forest adjacent to Paddys Run. Tall fescue (*Festuca elatior*) is dominant in many of the old-fields and grassy meadows. Lady's thumb (*Polygonum persicaria*) is abundant in the wet and disturbed areas.

We added 50 (15 percent) new species during 1999, which is a bit unusual for a second field season of a floristic analysis. In fact, only 6 (ca. 2 percent) of the 15 percent represents previously undiscovered species from habitats examined in the previous year (i.e., not streambed). In 1999, the Palmer Drought Severity Index (PDSI) for the Cincinnati, OH region was ca. –3.0 (severe drought) for the entire latter half of the growing season (NOAA 1999). As a result, most of Paddys Run dried up except for the larger pools. The resulting exposed sand and gravel bars revealed a large number of ephemeral species characteristic of floodplain habitats that experience regular hydrological disturbance. In fact, we even discovered an agricultural species (an unidentified melon, Cucurbitae) that had become established in the riverbed. These riparian "disturbance species" have been added to the list of vascular species and may prove useful in subsequent riparian remediation projects.

We did not discover any State or Federally threatened or endangered species known to occur in Hamilton or Butler Counties (ODNR 1997). In 1998 we noted the perplexing lack of "lower" vascular plant species (ferns and fern allies). After performing an exhaustive search for members of these groups, we discovered an additional 3 taxa: sparse-lobed grape fern (*Botrychium biternatum*), northern adder's-tongue, (*Ophioglossum vulgatum* var. *pseudopodium*), and the toothed wood-fern (*Dryopteris carthusiana*). However, all three species remain a special interest because we found only 1-10 individuals (abundance rating = 1) of each for the entire site, and they were thus amongst the most locally rare taxa encountered. Only the ebony spleenwort (*Asplenium platyneuron*) has a sufficient population size to maintain itself. Special effort should be relegated in the future towards understanding the lack of ferns at the site and exploring possible remediation solutions. With the exception of one other species (red cedar, *Juniperus virginiana*), all remaining 327 species were flowering plants (Angiosperms).

One taxon deserves special mention because of the tenuousness of its identification and improbability. We discovered one mature oak (*Quercus*) tree in an old-field that did not key to any known local species and was clearly a hybrid. Hybrids are known to be abundant in this genus. The vegetative features (no reproductive material was available) of this taxon bore a very strong resemblance to a known natural hybrid, *Quercus* × *bushii*. This cross represents a natural hybrid between black oak (*Q. velutina*) and blackjack oak (*Q. marilandica*). The problem with this identification is that neither black oak nor blackjack oaks were ever encountered at Fernald. Black oak is relatively common in Hamilton and Butler Counties, but blackjack oak is known only from several of the southernmost counties in Ohio (Adams, Gallia, Highland, Ross, and Scioto). Several possibilities exist: (1) this is an extremely unusual specimen of black oak, (2) it represents a previously undescribed hybrid from species present at Fernald, (3) the specimen originated as a long distance dispersal event from southern counties. In any event, it is a valid taxon to appear on the floristic list due to its uniqueness, and we had enough information to not warrant it being listed as unidentified ("sp."). We are quite confident of the identification of the other hybrid oak we encountered (*Quercus* × *runcinata)* because both parent species are present on the site and the characters of the specimen fit well with descriptions of this hybrid.

Given our sampling effort, we are fairly certain that we have recovered 95+ percent of the vascular plant species in the study area at FEMP. Because of chance encounter events not every species will be found. Migration, local extinction, herbivory, and ultimately sampling intensity always limit any checklist (Palmer et. al. 1995).

Experimental Study of Amur Honeysuckle

Phase-II of this research was designed to conduct a 3-year study of control methods for the invasive Amur honeysuckle (*Lonicera maackii*) and investigate how the native understory of hardwood species might best be restored (both ecologically and economically). Here we report on the initial design and implementation of this experiment and present preliminary results from the first field season.

Without question, Amur honeysuckle is the most problematic invasive species in southwestern Ohio. This species has come to dominate the understory and midstory of many hardwood stands both locally at FEMP, and regionally. Numerous studies have shown that this plant can reduce the natural germination, recruitment, and growth of native trees and herbs (Luken 1990, Nyboer 1992, Whelan 1992, Luken and Goessling 1995, Luken and Thieret 1996, Hutchinson and Vankat 1997). The net result is an overall

reduction in biodiversity, both locally and regionally, as well as disruption to a variety of ecosystem functions (Luken and Mattimiro 1991, Luken et. al. 1997).

There were three specific goals of this experiment: (1) to evaluate the efficacy of methods to control Amur honeysuckle (2) to compare the survival and growth of six species of native tree seedlings planted in plots where honeysuckle was subjected to different eradication measures, and (3) to evaluate the effectiveness of plastic browse tubes to control deer herbivory on planted 1-year tree seedlings.

This experiment was established as a completely randomized block design. This is the most appropriate design when dealing with heterogeneous forest conditions. Eight 5.5 x 13.5 m blocks were established throughout two stands on the eastern side of the North Woodlot. Each block was then fenced with two strands of barbwire below 1 m to exclude cattle but not deer. Each block was sub-divided in to three equal sized plots and treatments were randomly assigned to each plot. The treatments consisted of an experimental "control" (no manipulation of honeysuckle), and two eradication treatments, "cut" (honeysuckle was cut at ground level and removed from the plots, then stumps were painted with herbicide), and "injection" (honeysuckle was killed in plots via herbicide injection, but left standing *in situ*). In each treatment plot, ten seedlings of the following six species of native trees were planted: Chinquapin oak (*Quercus muehlenbergii*), black walnut (*Juglans nigra*), black cherry (*Prunus serotina*), green ash (*Fraxinus pennsylvanica*), flowering dogwood (*Cornus florida*), and redbud (*Cercis canadensis*). All six species are known from the flora of the Northern Woodlot (see appendix for species list); therefore, these species were appropriate selections for restoration efforts at FEMP. Deer browse tubes were added to half of the seedlings in each plot. As per FEMP regulations, the maintenance crew applied the cut and injection treatments to the appropriate plots (March 24, 1999) and planted the seedlings (March 24, 1999 to March 30, 1999). The crew also staked and applied the browse tubes to the tree seedlings (March 31, 1999 to April 13, 1999).

To determine if honeysuckle was equally abundant in all plots prior to treatment application, we constructed a regression model from plants harvested on site. Basal diameter was able to explain a significant portion of the variance in biomass (N=32 plants, $R^2 = 0.99$). Thus, basal diameter measurements were collected for all honeysuckle plants in all treatment plots. Subsequently, an analysis of variance indicated that there was an equivalent biomass of honeysuckle in all blocks and all treatment plots ($P > 0.10$). Thus, we were able to confirm at the beginning of the experiment that there were no pretreatment differences in honeysuckle biomass that needed to be considered prior to implementation of the design.

Within blocks, all honeysuckle plants were tagged to facilitate subsequent monitoring of treatment efficacy and evaluation of any new honeysuckle recruits (untagged) in to the blocks. All tree seedlings were also provided with a numbered aluminum tag to monitor individual survival, growth, and recruitment. Initial height and diameter of all tree seedlings were measured at the beginning of the experiment to determine if seedlings were homogenous in size distributions across all blocks and plots. Tree seedlings were found not to differ significantly ($P < 0.10$) among blocks or plots.

A number of microenvironmental factors were also analyzed to understand the variation among blocks and conditions affecting the tree seedlings in treatment plots. Soils were assessed for moisture, nitrate nitrogen, and pH. All soil analyses were conducted at the Forest Ecology Laboratory at Ohio University using the methods of McCarthy (1997). Soil moisture was examined three times during the growing season (May 30, June 25, and August 21, 1999). Percent soil moisture was determined gravimetrically. Some blocks were found to be significantly ($P < 0.05$) wetter than others. Nitrate nitrogen was sampled using Rexyn-300 resin enclosed in nylon mesh bags and buried in the A-horizon for 30 days. Nitrate was then extracted from the resin using 2M KCl and analyzed for nitrate concentration using a cadmium reduction protocol (McCarthy 1997). Like moisture, there was a significant ($P < 0.05$) block effect. The pH was determined by using a corning pH meter in a 1:1 soil and water solution. Likewise, pH exhibited a significant ($P < 0.001$) block effect. Humidity and air temperature were also determined inside and outside of browse tubes using a Corning Thermohygrometer. Both the humidity and temperature within browse tubes were found to be significantly ($P < 0.05$) greater than ambient. Understory light conditions were measured indirectly using hemispherical photography. Canopy images were captured on 35 mm film (July 30, 1999) using a hemispherical fisheye lens (8mm), digitized, and evaluated using the GLIC software of Canham (1988). This is one of the few methods that adequately describes both direct and indirect solar radiation available at ground level. A full description of the protocol can be found in Robison and McCarthy (1999). Light data have not yet been statistically analyzed.

The fact that microenvironmental differences can be found among plots confirms the necessity and appropriateness of the randomized complete block design. The effect of block can be removed from the model prior to the statistical evaluation of treatment effects.

Mortality of honeysuckle in the two treatment plots was found to be 99 percent at the end of the growing season. There was no significant ($P > 0.10$) difference between the two eradication methods. Thus, given its expediency and cost effectiveness, injection appears to be the best economical means of honeysuckle control, particularly for large plants. Small plants may still require a cut and herbicide approach.

In addition to the initial measurements, the 1,440 seedlings were monitored at two other times during the growing season to assess survivorship (May 27, 1999 and October 10, 1999). We examined each seedling, determined whether it was alive or dead (via a top-kill designation) and noted mode of mortality if relevant. By the end of the first growing season, seedling mortality was 49.8 percent. This was higher than expected and was primarily due to the severe drought that seedlings were exposed to in the middle and end of the growing season (PDSI values $\leq$ -3). We also noted differential survival among blocks, treatments, species, and tubed seedlings. The differences among blocks can be attributed to environmental heterogeneity. Survival of seedlings was greatest in the cut plots (57.4 percent), intermediate in the injection plots (53.1 percent), and lowest in the control plots (40.4 percent); however, there was no significant difference between the two treatment methods. This indicates that the primary difference is that the removal treatments (collectively) differ from the controls (1 df F-test). There was differential survival of the species as well: green ash (85.0 percent), chinquapin oak (60.4 percent), black walnut (54.2 percent), black cherry (47.9 percent), redbud (36.3 percent), flowering dogwood (15.0 percent). The survival of redbud was low because of poor handling at the beginning of the experiment (evidenced by immediate apical bud necrosis). Most redbuds were subsequently able to re-sprout from their bases, but then most died in the latter half of the summer when the severity of the drought increased. The survival of dogwood was also low due to transplant shock and droughty conditions. These two slower growing, midstory species may require more care in establishment than species with overstory potential.

Overall, survival was greater in non-tubed vs. tubed seedlings (55.6 vs. 44.3 percent). However, the survival of species in tubes was species dependent. For this field season, the survival frequencies of green ash and chinquapin oak were greatest when tubed, while the survival frequencies of redbud, dogwood, black walnut, and black cherry were greater in non-tubed conditions. The overall frequency of deer browsing for non-tubed seedlings was 12.4 percent. However, to be cautious, what is important is the amount of grazing over the 3-year period of the experiment and survival in the sapling size class. The frequency of browsing was related only to species and not to block or treatment. The frequency of browsing by species was: redbud (21.7 percent), dogwood (18.3 percent), black cherry (16.7 percent), chinquapin oak (13.3 percent), green ash (2.5 percent), black walnut (1.7 percent).

In addition to the initial morphometric measurements, we measured height growth (mm) and basal diameter (0.1 mm) on the 1,440 seedlings again on October 10, 1999. The effect of block was significant for height growth, but not for diameter growth. Height growth was not significantly ($P > 0.10$) affected by treatment or tube; however, species was important ($P < 0.05$). Generally, all species grew 4-7 mm in

height during the growing season with the one exception of ash, which exhibited a mean growth of 15.8 mm. Diameter growth ranged from 0.14 to 0.54 mm. Diameter growth was not significantly ($P > 0.10$) influenced by block, treatment, tube, or species.

Conclusions: First Year After Honeysuckle Removal

Overall, we found a distinct treatment effect for survival, but not for growth. Seedling survival was greatest in the plots where honeysuckle had been removed. Removal of honeysuckle should promote increased survival of woody seedlings in the understory. Browsing by deer was relatively low (ca. 12 percent). Most seedling mortality was caused by drought. Browse tubes actually decreased the survival of some species. Green ash was the strongest with respect to height growth. Additional time will be required to determine if these patterns persist. Monitoring over the next 2 years will permit us to assess the meso-term success of treatments, browse tubes, and species selections for subsequent restoration efforts.

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Table 1. Summary statistics for the major taxonomic groups and proportion of non-indigenous species identified from the north woodlot at FEMP.

Division*	Families	Genera	Species	% Non-Ind.
Lycopodiophyta	0	0	0	---
Equisetophyta	0	0	0	---
Polypodiophyta	2	4	4	0
Pinophyta	1	1	1	0
Magnoliophyta				
Magnoliopsida	63	175	247	31
Liliopsida	9	23	80	31
Totals	75	203	332	30

* Lycopodiophyta = lycopods
Equisetophyta = horsetails
Polypodiophyta = ferns
Pinophyta = cone-bearing plants ("pines")
Magnoliophyta = flowering plants
Magnoliopsida = dicots
Liliopsida = monocots

Taxa	Abundance Score[1]	Habitats Present[2] D	MM	OF	FT	FO	FEMP Identification	Indigenous/ Non-indigenous[3]
FERN AND FERN ALLIES								
Aspleniaceae								
Asplenium platyneuron (L.) Oakes	2			+			FEMP 111 MR	IND
Dryopteris carthusiana (Villars) H. P. Fuchs.	1				+		FEMP 337 MR	IND
Ophioglossaceae								
Botrychium biternatum (Savigny) Underw.	1				+		FEMP 400 MR	
Ophioglossum vulgatum var. *pseudopodum* (S. F. Blake) Farw.	1				+		FEMP 340 MR	IND
GYMNOSPERMS								
Cupressaceae								
Juniperus virginiana var. *virginiana* L.	4			+	+		FEMP 046 MR	IND
ANGIOSPERMS								
Aceraceae								
Acer negundo var. *negundo* L.	5			+	+	+	FEMP 028 MR	IND
Acer nigrum Michx. f.	5				+	+	FEMP 171 MR	IND
Acer rubrum L.	2		+	+			FEMP 176 MR	IND
Acer saccharinum L.	4		+	+	+	+	FEMP 108 MR	IND
Acer saccharum Marshall	4				+	+	FEMP 026 MR	IND
Amaranthaceae								
Amaranthus arenicola I. M. Johnst.	1	+					FEMP 301 MR	NON-IND
Amaranthus spinosus L.	2			+			FEMP 221 MR	NON-IND
Anacardiaceae								
Rhus glabra L.	2				+		FEMP 167 MR	IND
Rhus typhina L.	2				+		FEMP 174 MR	IND
Toxicodendron radicans (L.) Kuntze	5	+	+	+	+	+	FEMP 336 MR	IND
Annonaceae								
Asimina triloba (L.)Dunal	1					+	FEMP 380 MR	IND

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Apiaceae							
Aethusa cynapium L.	2			+		FEMP 153 MR	NON-IND
Chaerophyllum procumbens (L.) Crantz.	2		+	+	+	FEMP 025 MR	IND
Conium maculatum L.	2	+		+		FEMP 139 MR	NON-IND
Cryptotaenia canadensis (L.) DC	1				+	FEMP 095 MR	IND
Daucus carota L.	4		+	+		FEMP 212 MR	NON-IND
Hydrocotyle americana L.	3		+		+	FEMP 312 MR	IND
Osmorhiza claytonii (Michx.) C. B. Clarke	1				+	FEMP 034 MR	IND
Pastinaca sativa L.	3		+	+		FEMP 088 MR	NON-IND
Sanicula canadensis L.	1				+	FEMP 330 MR	IND
Sanicula gregaria E. Bickn.	1				+	FEMP 334 MR	IND
Torilis japonica (Houtt.) DC	1		+	+		FEMP 218 MR	NON-IND
Zizia aurea (L.) Koch	2		+		+	FEMP 360 MR	IND
Apocynaceae							
Apocynum cannabinum L.	3			+		FEMP 238 MR	IND
Aristolochiaceae							
Asarum canadense L.	1				+	FEMP 039 MR	IND
Asclepiadaceae							
Asclepias incarnata var. *incartata* L.	2			+		FEMP 276 MR	IND
Asclepias syriaca L.	2		+	+		FEMP 288 MR	IND
Asclepias tuberosa var. *interior* (Woodson) Shinners	2			+		FEMP 186 MR	IND
Asteraceae							
Achillea millefolium L.	3	+		+	+	FEMP 006 MR	NON-IND
Ambrosia artemisiifolia L.	4			+	+	FEMP 246 MR	IND
Ambrosia trifida var. *trifida* L.	1			+		FEMP 258 MR	IND
Arctium minus Schk.	3			+	+	FEMP 313 MR	NON-IND
Arctium tomentosum Miller	4	+		+		FEMP 242 MR	NON-IND
Artemisia annua L.	2	+				FEMP 387 MR	NON-IND
Aster novae-angliae L.	3		+	+		FEMP 271 MR	IND
Aster patens var. *phlogifolius* (Muhl.) Nees.	2			+		FEMP 275 MR	IND
Aster paternus Cronq.	4		+	+		FEMP 290 MR	IND
Aster pilosus var. *pilosus* Willd.	4			+	+	FEMP 277 MR	IND
Aster racemosus Elliott	2			+	+	FEMP 232 MR	IND
Bidens discoidea (T. & G.) Britton	2			+		FEMP 273 MR	IND
Bidens frondosa L.	3	+		+	+	FEMP 274 MR	IND
Carduus nutans L.	2			+		FEMP 136 MR	NON-IND

Cichorium intybus L.	3	+	+	+			FEMP 209 MR	NON-IND
Cirsium discolor (Muhl.) Sprengel	3	+		+			FEMP 239 MR	IND
Cirsium muticum Michx.	2		+				FEMP 287 MR	IND
Conyza canadensis var. *canadensis*(L.) Cronq.	3			+			FEMP 235 MR	IND
Eclipta prostrata (L.) L.	1	+			+		FEMP 267 MR	NON-IND
Erigeron philadelphicus L.	3	+	+	+	+		FEMP 084 MR	IND
Erigeron pulchellus var. *pulchellus* Michx.	1			+	+		FEMP 054 MR	IND
Eupatorium altissimum L.	1			+			FEMP 317 MR	IND
Eupatorium perfoliatum var. *perfoliatum* L.	2			+			FEMP 269 MR	IND
Eupatorium rugosum var. *rugosum* Houttuyn	5	+	+	+	+	+	FEMP 253 MR	IND
Eupatorium serotinum Michx.	2			+	+		FEMP 230 MR	IND
Euthamia graminifolia var. *graminifolia* (L.) Nutt.	4		+	+			FEMP 233 MR	IND
Helianthus tuberosus L.	2	+		+			FEMP 319 MR	IND
Lactuca saligna L.	1	+					FEMP 248 MR	NON-IND
Lactuca serriola var. *integrata* Gren. & Gordon	2			+			FEMP 292 MR	NON-IND
Rudbeckia triloba var. *triloba* L.	3		+		+		FEMP 263 MR	IND
Senecio obovatus Muhl.	1					+	FEMP 031 MR	IND
Senecio glabellus Poir.	1		+	+			FEMP 058 MR	IND
Solidago juncea Aiton	4			+			FEMP 237 MR	IND
Solidago canadensis var. *canadensis* L.	5			+			FEMP 281 MR	IND
Solidago canadensis var. *scabra* T. & G.	5			+			FEMP 282 MR	IND
Sonchus arvensis var. *glabrescens* (Guenther) Grab. & Wimmer	1	+		+			FEMP 143 MR	NON-IND
Sonchus asper (L.) Hill	1	+					FEMP 359 MR	NON-IND
Taraxacum officinale Weber ex Wiggers	3	+		+		+	FEMP 002 MR	NON-IND
Tragopogon pratensis L.	1	+					FEMP 199 MR	NON-IND
Vernonia gigantea var. *gigantea* (Walter) Trel.	5			+	+		FEMP 241 MR	IND
Verbesina alternifolia (L.) Britton	2			+	+		FEMP 318 MR	IND
Verbesina helianthoides Michx.	2			+	+		FEMP 257 MR	IND
Xanthium strumarium var. *glabratum* (DC) Cronq.	4	+	+	+			FEMP 272 MR	IND
Balsaminaceae								
Impatiens capensis Meerb.	2				+	+	FEMP 166 MR	IND
Impatiens pallida Nutt.	2	+			+		FEMP 208 MR	IND
Berberidaceae								
Podophyllum peltatum L.	2	+				+	FEMP 024 MR	IND
Betulaceae								
Carpinus caroliniana var. *caroliniana* Walter	1					+	FEMP 040 MR	IND

Bignoniaceae								
Campsis radicans (L.) Seemann	2	+			+		FEMP 215 MR	IND
Boraginaceae								
Hackelia virginiana (L.) I. M. Johnston	1			+	+		FEMP 259 MR	IND
Brassicaceae								
Alliaria petiolata (Bieb.) Cavara & Grande	4		+		+	+	FEMP 020 MR	NON-IND
Barbarea vulgaris R. Br.	4	+	+	+	+		FEMP 045 MR	NON-IND
Brassica nigra L.	1	+					FEMP 353 MR	NON-IND
Capsella bursa-pastoris (L.) Medikus	2		+				FEMP 338 MR	NON-IND
Cardamine concatenata (Michx.) O. Schwarz	2					+	FEMP 339 MR	IND
Cardamine hirsuta L.	2				+		FEMP 335 MR	NON-IND
Draba verna L.	3		+				FEMP 060 MR	NON-IND
Hesperis matronalis L.	2	+					FEMP 356 MR	NON-IND
Iodanthus pinnatifidis (Michx.) Steudel	1			+			FEMP 094 MR	IND
Lepidium campestre (L.) R. Br.	3		+	+			FEMP 011 MR	NON-IND
Lepidium virginicum var. *virginicum* L.	1			+			FEMP 144 MR	IND
Rorippa palustris var. *fernaldiana* (Butters & Abbe) Stuckey	1			+			FEMP 348 MR	IND
Rorippa sylvestris (L.) Besser	1			+			FEMP 137 MR	NON-IND
Sisymbrium officinale (L.) Scop.	1			+			FEMP 141 MR	NON-IND
Thlaspi arvense L.	1			+			FEMP 138 MR	NON-IND
Caesalpiniaceae								
Cercis canadensis var. *canadensis* L.	1				+		FEMP 310 MR	IND
Gleditsia triacanthos L.	3			+	+	+	FEMP 123 MR	IND
Gymnocladus dioica (L.) K. Koch	2				+	+	FEMP 041 MR	IND
Campanulaceae								
Campanula americana L.	2	+				+	FEMP 345 MR	IND
Lobelia inflata L.	3		+		+		FEMP 264 MR	IND
Lobelia siphilitica var. *siphilitica* L.	3	+	+				FEMP 262 MR	IND
Caprifoliaceae								
Lonicera japonica Thunb.	4		+	+	+	+	FEMP 048 MR	NON-IND
Lonicera maackii (Rupr.) Maxim.	5			+	+		FEMP 017 MR	NON-IND
Sambucus canadensis var. *canadensis* L.	2				+		FEMP 216 MR	IND
Viburnum prunifolium L.	1				+		FEMP 013 MR	IND

Caryophyllaceae							
Cerastium vulgatum L.	4		+	+	+	FEMP 008 MR	NON-IND
*Dianthus armeria*L.	2		+	+		FEMP 087 MR	NON-IND
Saponaria officinalis L.	1				+	FEMP 293 MR	NON-IND
Silene latifolia Poiret	2	+	+			FEMP 358 MR	NON-IND
Stellaria media (L.) Villars.	5		+		+	FEMP 009 MR	NON-IND
Chenopodiaceae							
Chenopodium album L.	1	+				FEMP 303 MR	NON-IND
Clusiaceae							
Hypericum prolificum L.	1			+		FEMP 350 MR	IND
Hypericum punctatum Lam.	1			+		FEMP 349 MR	IND
Commelinaceae							
Commelina communis L.	3		+	+	+	FEMP 260 MR	NON-IND
Convolvulaceae							
Calystegia sepium (L.) R. Br.	3	+		+		FEMP 201 MR	IND
Ipomoea hederacea Jacq.	1	+				FEMP 352 MR	NON-IND
Ipomoea lacunosa L.	1			+		FEMP 244 MR	IND
Ipomoea pandurata (L.) G. Meyer	1			+		FEMP 236 MR	IND
Cornaceae							
Cornus drummondii C. A. Meyer	4			+	+	FEMP 107 MR	IND
Cornus racemosa Lam.	2			+	+	FEMP 270 MR	IND
Cucurbitaceae							
Cucurbita sp. (L.)	1	+				FEMP 389 MR	NON-IND
Sicyos angulatus L.	1	+				FEMP 355 MR	IND
Cyperaceae							
Carex albursina Sheldon	1				+	FEMP 177 MR	IND
Carex blanda Dewey	1				+	FEMP 093 MR	IND
Carex cephalophora var. *cephalophora* Muhl.	1		+	+		FEMP 134 MR	IND
Carex cristatella Britton	2		+			FEMP 101 MR	IND
Carex davisii Schwein. & Torr.	1		+	+		FEMP 329 MR	IND
Carex frankii Kunth.	2		+			FEMP 321 MR	IND
Carex granularis Muhl.	1		+	+		FEMP 326 MR	IND
Carex hystericina Muhl.	1				+	FEMP 159 MR	IND

Carex joorii L. Bailey	2		+		FEMP 075 MR	IND
Carex scoparia Schk.	2	+	+		FEMP 320 MR	IND
Carex shortiana Dewey	2	+	+		FEMP 089 MR	IND
Carex tribuloides Wahlenb.	1	+	+		FEMP 328 MR	IND
Carex vulpinoidea var. *vulpinoidea* Michx.	3	+	+		FEMP 073 MR	IND
Cyperus lancastriensis Porter	2	+			FEMP 217 MR	IND
Cyperus strigosus L.	2	+	+		FEMP 213 MR	IND
Eleocharis ovata (Roth) Roemer & Schultes	2	+			FEMP 016 MR	IND
Scirpus atrovirens var. *atrovirens* Willd.	2	+	+		FEMP 181 MR	IND
Scripus lineatus Michx.	2	+	+		FEMP 071 MR	IND
Dioscoreaceae						
Dioscorea villosa L.	2	+		+	FEMP 315 MR	IND
Dipsacaceae						
Dipsacus sylvestris Hudson	2	+	+		FEMP 210 MR	NON-IND
Elaeagnaceae						
Elaeagnus angustifolia L.	2	+	+	+	FEMP 047 MR	NON-IND
Elaeagnus multiflora Thunb.	1			+	FEMP 283 MR	NON-IND
Euphorbiaceae						
Acalypha rhomboidea Raf.	3			+	FEMP 286 MR	IND
Euphorbia dentata Michx.	1	+			FEMP 297 MR	IND
Euphorbia maculata L.	1	+			FEMP 256 MR	IND
Euphorbia nutans Lagasca	1			+	FEMP 323 MR	IND
Fabaceae						
Amorpha fruticosa L.	1			+	FEMP 255 MR	IND
Desmodium paniculatum (L.) DC	2		+	+	FEMP 219 MR	IND
Lespedeza violacea (L.) Pers.	3		+		FEMP 247 MR	IND
Medicago lupulina L.	1	+			FEMP 327 MR	NON-IND
Melilotus abla Medikus	1	+			FEMP 361 MR	NON-IND
Melilotus officinalis (L.) Pallas	2		+		FEMP 133 MR	NON-IND
Robinia pseudoacacia L.	2			+	FEMP 131 MR	IND
Trifolium campestre Schreber	2	+	+		FEMP 063 MR	NON-IND
Trifolium dubium Sibth.	3	+			FEMP 065 MR	NON-IND
Trifolium hybridum L.	2	+	+		FEMP 085 MR	NON-IND
Trifolium pratense L.	3	+	+		FEMP 064 MR	NON-IND
Trifolium repens L.	4	+	+		FEMP 067 MR	NON-IND

Fagaceae								
Quercus alba L.	3				+	+	FEMP 162 MR	IND
Quercus bicolor Willd.	4				+	+	FEMP 173 MR	IND
Querucs x *bushii* Sarg.	1			+			FEMP 351 MR	IND
Quercus imbricaria Michx.	3			+	+	+	FEMP 117 MR	IND
Quercus muehlenbergii Engelm.	4				+	+	FEMP 118 MR	IND
Quercus rubra L.	3				+	+	FEMP 170 MR	IND
Quercus x *runcinata* (A. DC) Engelm.	1			+			FEMP 304 MR	IND
Quercus shumardii Buckley	3				+	+	FEMP 126 MR	IND
Fumariaceae								
Corydalis flavula (Raf.) DC	2				+	+	FEMP 042 MR	IND
Dicentra cucullaria (L.) Bernh.	2					+	FEMP 038 MR	IND
Hippocastanaceae								
Aesculus glabra var. *glabra* Willd.	2				+	+	FEMP 022 MR	IND
Hydrophyllaceae								
Phacelia purshii Buckley	2		+		+		FEMP 081 MR	IND
Iridaceae								
Sisyrinchium angustifolium Miller	1		+				FEMP 103 MR	IND
Juglandaceae								
Carya cordiformis (Wangenh.) K. Koch	3				+	+	FEMP 179 MR	IND
Carya glabra (Miller) Sweet	2				+	+	FEMP 152 MR	IND
Carya laciniosa (Michx. f.) Nutt.	5				+	+	FEMP 148 MR	IND
Carya ovata (Miller) K. Koch	1				+		FEMP 314 MR	IND
Juglans nigra L.	5				+	+	FEMP 130 MR	IND
Juncaceae								
Juncus tenuis var. *tenuis* Willd.	5	+	+	+			FEMP 083 MR	IND
Lamiaceae								
Agastache nepetoides (L.) Kuntze	1	+					FEMP 185 MR	IND
Glechoma hederacea L.	4	+	+	+	+	+	FEMP 004 MR	NON-IND
Lamium purpureum L.	4	+	+			+	FEMP 005 MR	NON-IND
Mentha arvensis var. *canadensis* (L.) Kuntze	3			+	+		FEMP 265 MR	IND
Mentha x *piperita* L.	1			+			FEMP 222 MR	NON-IND

Nepeta cataria L.	1	+					FEMP 346 MR	NON-IND
Prunella vulgaris var. *vulgaris* L.	3		+		+	+	FEMP 211 MR	NON-IND
Teucrium canadense var. *virginicum* (L.) Eaton	1	+					FEMP 354 MR	IND
Lemnaceae								
Lemna minor L.	1					+	FEMP 129 MR	IND
Liliaceae								
Allium canadense var. *canadense* L.	2		+		+	+	FEMP 099 MR	IND
Allium vineale L.	3		+		+	+ +	FEMP 018 MR	NON-IND
Trillium sessile L.	1					+	FEMP 035 MR	IND
Malvaceae								
Abutilon theophrasti Medikus	1	+					FEMP 343 MR	NON-IND
Sida spinosa L.	1	+			+		FEMP 243 MR	IND
Menispermaceae								
Menispermum canadense L.	3		+			+	FEMP 079 MR	IND
Molluginaceae								
Mollugo verticillata L.	1	+					FEMP 261 MR	NON-IND
Moraceae								
Maclura pomifera (Raf.) C. K. Schneider	1	+	+			+	FEMP 295 MR	NON-IND
Morus rubra L.	2				+	+	FEMP 132 MR	IND
Oleaceae								
Fraxinus americana L.	3					+	FEMP 165 MR	IND
Fraxinus pennsylvanica Marshall	5				+	+ +	FEMP 163 MR	IND
Fraxinus pennsylvanica var. *subintegerrima* (Vahl) Fern	5				+	+ +	FEMP 164 MR	IND
Onagraceae								
Circaea lutetiana var. *canadensis* L.	1					+	FEMP 178 MR	IND
Epilobium coloratum Biehler	1	+					FEMP 388 MR	IND
Ludwigia alata Elliot	1		+				FEMP 086 MR	IND
Oenothera biennis var. *biennis* L.	2	+			+		FEMP 140 MR	IND
Oenothera fruticosa L.	1	+					FEMP 386 MR	IND
Oxalidaceae								
Oxalis dillenii Jacq.	2					+ +	FEMP 082 MR	IND

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Oxalis stricta L.	3		+		+	+	FEMP 154 MR	IND
Phytolaccaceae								
Phytolacca americana L.	1	+					FEMP 200 MR	IND
Plantaginaceae								
Plantago lanceolata L.	4	+	+	+			FEMP 066 MR	NON-IND
Plantago major L.	4	+	+	+	+		FEMP 251 MR	IND
Plantago rugelii Decne.	3	+	+	+			FEMP 191 MR	IND
Platanaceae								
Platanus occidentalis L.	4			+	+	+	FEMP 175 MR	IND
Poaceae								
Agrostis perennans var. *perennans* (Walter) Tuckerman	5	+	+	+			FEMP 091 MR	IND
Alopecurus pratensis L.	2			+			FEMP 135 MR	NON-IND
Andropogon virginicus var. *virginicus* L.	2			+			FEMP 306 MR	IND
Bromus commutatus Schrader	2			+			FEMP 145 MR	NON-IND
Bromus inermis Leysser	2	+	+				FEMP 195 MR	NON-IND
Bromus sterilis L.	2	+	+				FEMP 194 MR	NON-IND
Dactylis glomerata L.	4	+	+	+			FEMP 077 MR	NON-IND
Digitaria ischaemum (Schreber) Muhl.	3	+	+	+			FEMP 245 MR	NON-IND
Digitaria sanguinalis (L.) Scop.	2	+	+	+			FEMP 364 MR	NON-IND
Echinochloa crusgalii var. *crusgalii* (L.) P. Beauv.	3	+	+	+			FEMP 278 MR	NON-IND
Echinochloa muricata var. *muricata* (L.) P. Beauv.	2	+	+	+			FEMP 226 MR	IND
Eleusine indica (L.) Gaertn.	1		+				FEMP 382 MR	NON-IND
Elymus hystrix L.	2			+	+		FEMP 149 MR	IND
Elymus villosus Muhl.	1			+			FEMP 198 MR	IND
Elymus virginicus L.	2				+		FEMP 227 MR	IND
Eragrostis spectabilis (Pursh.) Steudel.	2		+				FEMP 291 MR	IND
Festuca elatior L.	5		+	+			FEMP 069 MR	NON-IND
Festuca rubra L.	4		+	+			FEMP 325 MR	IND
Festuca subverticillata (Pers.) E. Alexeev.	2		+	+	+		FEMP 151 MR	IND
Glyceria striata (Lam.) A. Hitchc.	3		+		+	+	FEMP 156 MR	IND
Hordium pussilum L.	1	+					FEMP 142 MR	IND
Leersia oryzoides (L.) Swartz	3		+				FEMP 308 MR	IND
Leersia virginica Willd.	4		+	+	+	+	FEMP 225 MR	IND
Muhlenbergia schreberi J. F. Gmelin	3		+		+		FEMP 311 MR	IND
Panicum clandestinum L.	4		+	+	+		FEMP 307 MR	IND
Panicum lanuginosum var. *fasciculatum* (Torr.) Fern.	1			+			FEMP 362 MR	IND

Panicum lanuginosum var. *implicatum* (Scribn.) Fern.	1		+				FEMP 324 MR	IND
Panicum lanuginosum var. *lanuginosum* Elliot	1			+			FEMP 106 MR	IND
Paspalum pubiflorum var. *glabrum* Vasey.	1	+					FEMP 280 MR	IND
Paspalum setaceum var. *ciliatifolium* (Mischx.) Vasey	1	+					FEMP 196 MR	IND
Paspalum setaceum var. *muhlenbergii* (Nash) D. Banks	2	+	+				FEMP 322 MR	IND
Phleum pratense L.	1			+			FEMP 240 MR	NON-IND
Poa annua L.	3		+	+			FEMP 070 MR	NON-IND
Poa compressa L.	2		+	+			FEMP 072 MR	NON-IND
Poa pratensis L.	3		+	+	+	+	FEMP 061 MR	NON-IND
Poa sylvestris A. Gray	3				+	+	FEMP 096 MR	IND
Poa trivialis L.	2		+	+			FEMP 332 MR	NON-IND
Setaria faberi R. Herrm.	3	+		+			FEMP 231 MR	NON-IND
Setaria glauca (L.) P. Beauv.	3	+	+	+			FEMP 250 MR	NON-IND
Setaria viridis var. viridis (L.) P. Beauv.	4	+	+				FEMP 363 MR	IND
Tridens flavus var. *flavus* (L.) A. Hitchc.	4		+	+			FEMP 234 MR	IND
Triticum aestivum L.	1	+					FEMP 333 MR	NON-IND
Polemoniaceae								
Phlox divaricata var. *divaricata* L.	1					+	FEMP 032 MR	IND
Polygonaceae								
Polygonum aviculare L.	1	+	+				FEMP 207 MR	IND
Polygonum cespitosum var. *longisetum* (De Bruyn) Stewart	2				+		FEMP 124 MR	NON-IND
Polygonum hydropiper L.	2				+		FEMP 155 MR	NON-IND
Polygonum lapathifolium L.	3	+					FEMP 383 MR	IND
Polygonum pennsylvanicum L.	4	+	+	+			FEMP 298 MR	IND
Polygonum persicaria L.	5		+	+	+		FEMP 249 MR	NON-IND
Polygonum punctatum var. *punctatum* Elliott	2		+		+		FEMP 224 MR	NON-IND
Polygonum scandens var. *cristatum* (Englem. & A. Gray) Gleason	1				+		FEMP 254 MR	IND
Polygonum scandens var. scandens L.	1	+					FEMP 385 MR	IND
Polygonum virginianum L.	3				+	+	FEMP 252 MR	IND
Rumex crispus L.	2			+			FEMP 074 MR	NON-IND
Rumex obtusifolius L.	1				+		FEMP 158 MR	NON-IND
Portulacaceae								
Claytonia caroliniana Michx.	4		+	+	+	+	FEMP 036 MR	IND
Claytonia virginica var. *virginica* L.	2					+	FEMP 341 MR	IND
Primulaceae								
Lysimachia nummularia L.	4	+	+	+	+		FEMP 015 MR	NON-IND

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Samolus floribunds HBK	1		+				FEMP 302 MR	IND
Ranunculaceae								
Ranunculus abortivus var. *abortivus* L.	4		+		+	+	FEMP 001 MR	IND
Ranunculus micranthus Nutt.	1					+	FEMP 398 MR	IND
Rosaceae								
Agrimonia parviflora Aiton	4			+	+		FEMP 214 MR	IND
Crataegus crus-galli L.	1		+				FEMP 051 MR	IND
Crataegus x *disperma* Ashe	1			+			FEMP 146 MR	IND
Crataegus mollis (T. & G.) Scheele	1			+			FEMP 203 MR	IND
Duchesnea indica (Andrews) Focke.	1				+		FEMP 055 MR	NON-IND
Fragaria vesca var. *americana* Porter	1				+		FEMP 125 MR	IND
Geum vernum (Raf.) T. & G.	2		+		+	+	FEMP 050 MR	IND
Geum virginianum L.	1				+		FEMP 160 MR	IND
Potentilla norvegica L.	1		+				FEMP 347 MR	IND
Potentilla recta L.	2	+		+			FEMP 187 MR	NON-IND
Prunus avium L.	1				+		FEMP 289 MR	NON-IND
Prunus cerasus L.	1			+			FEMP 381 MR	NON-IND
Prunus hortulana L. H. Bailey.	1		+				FEMP 052 MR	IND
Prunus monsoniana Wight & Hedrick	1			+			FEMP 202 MR	IND
Prunus serotina Ehrh.	4				+	+	FEMP 014 MR	IND
Pyrus communis L.	1		+	+			FEMP 053 MR	NON-IND
Rosa carolina L.	3	+		+	+	+	FEMP 056 MR	IND
Rosa multiflora Thunb.	5	+	+	+	+	+	FEMP 033 MR	NON-IND
*Rosa setigera*Michx.	2		+				FEMP 357 MR	IND
Rubus allegheniensis T. C. Porter	3			+	+		FEMP 076 MR	IND
Rubus flagellaris Willd.	2			+			FEMP 305 MR	IND
Rubus occidentalis L.	2		+	+			FEMP 104 MR	IND
Rubiaceae								
Galium aparine var. *aparine* L.	3		+	+	+		FEMP 023 MR	IND
Galium triflorum var. *triflorum* Michx.	3		+		+		FEMP 044 MR	IND
Salicaceae								
Populus deltoides var. *deltoides* Marshall	2	+		+	+		FEMP 184 MR	IND
Salix eriocephala Michx.	1		+				FEMP 147 MR	IND
Salix exigua var. *angustissima* (Anderson) Reveal & Broome	1				+		FEMP 316 MR	IND
Salix nigra var. *nigra* Marshall	2			+			FEMP 279 MR	IND

Saxifragaceae								
Penthorum sedoides L.	1		+				FEMP 266 MR	IND
Scrophulariaceae								
Agalinis tenuifolia (M. Vahl) Raf.	3		+	+			FEMP 229 MR	IND
Mimulus alatus Aiton	2		+				FEMP 220 MR	IND
Penstemon digitalis Nutt.	2			+			FEMP 127 MR	IND
Verbascum blattaria L.	3	+	+				FEMP 161 MR	NON-IND
Verbascum thaspus L.	2	+					FEMP 183 MR	NON-IND
Veronica anagallis-aquatica L.	1		+				FEMP 128 MR	NON-IND
Veronica arvensis L.	3		+				FEMP 062 MR	NON-IND
Veronica serpyllifolia var. *serpyllifolia* L.	3		+				FEMP 059 MR	NON-IND
Simaroubaceae								
Ailanthus altissima (Miller) Swingle	2				+		FEMP 204 MR	NON-IND
Smilacaceae								
Smilax hispida Muhl.	2			+	+	+	FEMP 150 MR	IND
Solanaceae								
Datura stramonium L.	1	+					FEMP 342 MR	IND
Physalis longifolia var. *subglabrata* (Mackenzie & Bush) Cronq.	1	+					FEMP 344 MR	IND
Solanum carolinense L.	3	+	+	+			FEMP 188 MR	NON-IND
Solanum nigrum L.	1	+					FEMP 299 MR	IND
Tiliaceae								
Tilia americana var. *americana* L.	1				+		FEMP 284 MR	IND
Ulmaceae								
Celtis occidentalis L.	5				+	+	FEMP 120 MR	IND
Ulmus americana L.	3			+	+		FEMP 268 MR	IND
Ulmus rubra Muhl.	5			+	+	+	FEMP 113 MR	IND
Urticaceae								
Boehmeria cylindrica (L.) Swartz	2				+		FEMP 157 MR	IND
Pilea pumila (L.) A. Gray	3	+			+	+	FEMP 228 MR	IND
Valerianaceae								
Valerianella umbilicata (Sulliv.) A. Wood.	2			+	+	+	FEMP 080 MR	IND
Valerianella radiata (L.) Dufr.	2		+				FEMP 331 MR	IND

Verbenaceae							
Verbena urticifolia var *urticifolia* L.	3		+	+		FEMP 223 MR	IND
Violaceae							
Viola pubescens Aiton	3				+	FEMP 030 MR	IND
Viola sororia Willd.	4	+	+	+	+	FEMP 012 MR	IND
Vitaceae							
Parthenocissus quinquefolia (L.) Planchon	3			+	+	FEMP 043 MR	IND
Vitis labrusca L.	3				+	FEMP 300 MR	IND
Vitis vulpina L.	5		+	+		FEMP 102 MR	IND

[1] See Table 3 for Abundance Scores

[2] See Table 2 for Habitat descriptions; a "+" indicates a species' presence in the habitat

[3] IND = Indigenous
NON-IND = Non-indigenous