



Problematic Plant Monitoring in Hopewell Culture National Historical Park

2008–2019

Natural Resource Report NPS/HTLN/NRR—2021/2271



ON THE COVER

Habitat in Seip Unit, Hopewell Culture National Historical Park, Chillicothe, Ohio
Photography by NPS

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Abstract

Managers are challenged with the impact of problematic plants, including exotic, invasive, and pest plant species. Information on the cover and frequency of these plants is essential for developing risk-based approaches to managing these species. Based on surveys conducted in 2008, 2011, 2015, and 2019, Heartland Network staff and contractors identified a cumulative total of 51 potentially problematic plant species in Hopewell Culture National Historical Park. Of the 37 species found in 2019, we characterized 7 as very low frequency, 9 as low frequency, 17 as medium frequency, and 4 as high frequency. Of these, midpoint cover estimates of 2 medium frequency and 2 high frequency species exceeded the 10-acre threshold. Because of the number, extent, and cover of problematic plants in the park and the small park size, control efforts should focus on treating high priority species across the entire park. High priority species may include plant species capable of rapid spread, species at low population levels, and species which can effectively be controlled.

Introduction

The National Park Service’s management policies distinguish between native and exotic (i.e., non-native) plant species (NPS 2006). Exotic plant species are typically characterized by their introduction due to human actions, whether intentional or not. Invasive plants, following the definition used in Executive Order 13751, are those plants that are exotic and cause ecological or economic harm. Finally, pest plants are defined less by their biology and more by their context in the same way that the term *weed* is defined (NPS 2006). Pest plants, which include native species, interfere with a specific management objective, including an objective of protecting human health. We suggest thinking of this collection of exotic, invasive, and pest plants as *potentially problematic* species.

Park managers, however, are only required to control any problematic plants that lead to *resource impairment*. For plant populations causing effects that fall

short of the impairment threshold, park managers wield a high level of discretion in judging whether the population should be controlled or not. The standard for making this decision rests on five criteria: the origin of the species, prudence, feasibility, the harm (i.e., impact) that the plant causes to park resources, and the harm that removal causes (NPS 2006). As with impairment determinations, these decisions are based on professional judgment, environmental assessment, consultation with regulating agencies, evidence-based scholarship, subject matter expertise, and civic engagement with the public (NPS 2006).

This report presents the results of problematic plant monitoring conducted at Hopewell Culture National Historical Park (NHP) in 2008, 2011, 2015 and 2019. The key metrics presented include plant cover and geographic distribution within the park.



Amur honeysuckle, the most commonly encountered problematic plant in Hopewell Culture National Historical Park, Chillicothe, Ohio. NPS

Methods

All methods presented here are based on the Heartland Inventory and Monitoring Network invasive exotic plant monitoring protocol (Young et al. 2007).

Watch Lists

We searched for potentially problematic plants on two lists. Prioritized problematic plants not previously found during monitoring in the park constituted the early detection watch list (n = 66; Table 1).

Table 1. Early detection problematic plant watch list used to guide surveys in Hopewell Culture NHP.

Scientific Name	Common Name
<i>Acer ginnala</i>	Amur maple
<i>Acer platanoides</i>	Norway maple
<i>Alnus glutinosa</i>	European alder
<i>Ampelopsis brevipedunculata</i>	Amur peppervine
<i>Arthraxon hispidus</i>	small carpgrass
<i>Bromus</i> sp.	annual brome sp. (NOT <i>B. inermis</i>)
<i>Butomus umbellatus</i>	flowering rush
<i>Carduus nutans</i>	nodding plumeless thistle
<i>Centaurea solstitialis</i>	yellow star-thistle
<i>Centaurea stoebe</i> ssp. <i>micranthos</i>	spotted knapweed
<i>Cirsium</i> sp.	thistle sp.
<i>Clematis terniflora</i>	sweet autumn virginsbower
<i>Conium maculatum</i>	poison hemlock
<i>Cynanchum louiseae</i>	Louise's swallow-wort
<i>Datura stramonium</i>	jimsonweed
<i>Dipsacus laciniatus</i>	cutleaf teasel
<i>Dioscorea oppositifolia</i>	Chinese yam
<i>Egeria densa</i>	Brazilian waterweed
<i>Elaeagnus umbellata</i> / <i>angustifolia</i>	Russian/autumn olive complex
<i>Elaeagnus angustifolia</i>	Russian olive
<i>Elymus repens</i>	quackgrass
<i>Euphorbia cyparissias</i>	cypress spurge
<i>Euphorbia esula</i>	leafy spurge
<i>Hedera helix</i>	English ivy
<i>Holcus lanatus</i>	common velvetgrass
<i>Humulus japonicus</i>	Japanese hop
<i>Hypericum perforatum</i>	common St. Johnswort
<i>Iris pseudacorus</i>	paleyellow iris

Table 1 (continued). Early detection problematic plant watch list used to guide surveys in Hopewell Culture NHP.

Scientific Name	Common Name
<i>Lespedeza bicolor</i>	shrub lespedeza
<i>Lespedeza cuneata</i>	sericea lespedeza
<i>Ligustrum</i> sp.	privet sp.
<i>Ligustrum obtusifolium</i>	border privet
<i>Linaria vulgaris</i>	butter and eggs
<i>Lonicera xbella</i>	showy fly honeysuckle
<i>Lotus corniculatus</i>	bird's-foot trefoil
<i>Lotus tenuis</i>	narrow-leaf bird's-foot trefoil
<i>Lythrum salicaria</i>	purple loosestrife
<i>Miscanthus sinensis</i>	Chinese silvergrass
<i>Myriophyllum aquaticum</i>	parrot feather watermilfoil
<i>Myosotis scorpioides</i>	true forget-me-not
<i>Myriophyllum spicatum</i>	Eurasian watermilfoil
<i>Najas minor</i>	brittle waternymph
<i>Nasturtium officinale</i>	watercress
<i>Onopordum acanthium</i>	Scotch cottonthistle
<i>Paulownia tomentosa</i>	princesstree
<i>Phragmites australis</i>	common reed
<i>Populus alba</i>	white poplar
<i>Poa compressa</i>	Canada bluegrass
<i>Potamogeton crispus</i>	curly pondweed
<i>Polygonum perfoliatum</i>	Asiatic tearthumb
<i>Polygonum sachalinense</i>	giant knotweed
<i>Pueraria montana</i>	kudzu
<i>Rhamnus cathartica</i>	common buckthorn
<i>Rumex acetosella</i>	common sheep sorrel
<i>Schedonorus pratensis</i>	meadow fescue
<i>Sonchus arvensis</i>	field sowthistle
<i>Spiraea</i> sp.	spirea sp.
<i>Spiraea japonica</i>	Japanese meadowsweet, Japanese spirea
<i>Tanacetum vulgare</i>	common tansy
<i>Torilis japonica</i>	erect hedgeparsley
<i>Typha angustifolia</i>	narrowleaf cattail
<i>Typha xglauca</i>	hybrid cattail
<i>Typha</i> sp.	cattail sp.
<i>Vitis aestivalis</i>	summer grape
<i>Viburnum opulus</i>	European cranberrybush
<i>Wisteria floribunda</i>	Japanese wisteria

Prioritized problematic plants known to occur in the park based on previous monitoring constituted the park-established watch list ($n = 51$; Table 2). In this report we included only plant species that we searched for in 2019. Of these, any species not sought during all previous surveys are annotated in the table. While aquatic species were included on watch lists, terrestrial plants were the focus of this survey. Aquatic plants were documented only occasionally.

Field Methods

We searched for problematic plant species on designated watch lists (Tables 1 and 2) across Hopewell Culture NHP (Figure 1). Contracted staff conducted the monitoring during June 17–August 8, 2008, and July 7–16, 2011. NPS staff used Trimble GPS units to conduct monitoring during August 10–12, 2015, and August 12–15, 2019.

Observers made three roughly equidistant passes through each search unit, normally in the east to west direction. On each pass through the search units, observers estimated plant cover in a 3 to 12-m belt using the widest belt in which the observers were able to view plants and pooled those estimates for the entire unit. Cover was summarized for each plant taxon within each search unit using these cover values: 0 = 0, 1 = 0.1–0.9 m², 2 = 1–9.9 m², 3 = 10–49.9 m², 4 = 50–99.9 m², 5 = 100–499.9 m², 6 = 500–999.9 m², 7 = 1,000–4,999.9 m². The same 107 search units were surveyed each time (Figure 1).

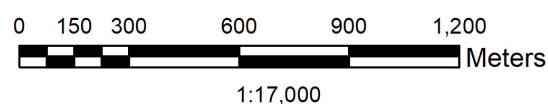
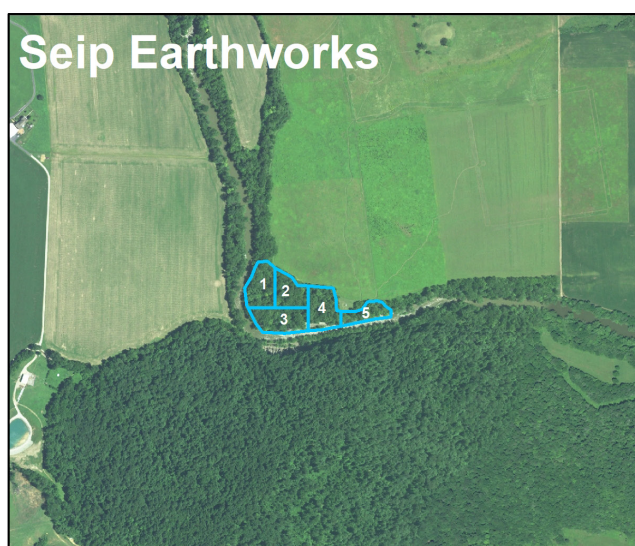
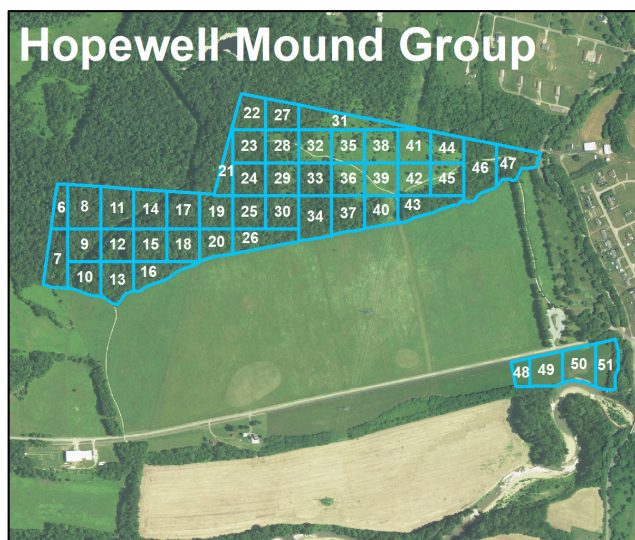
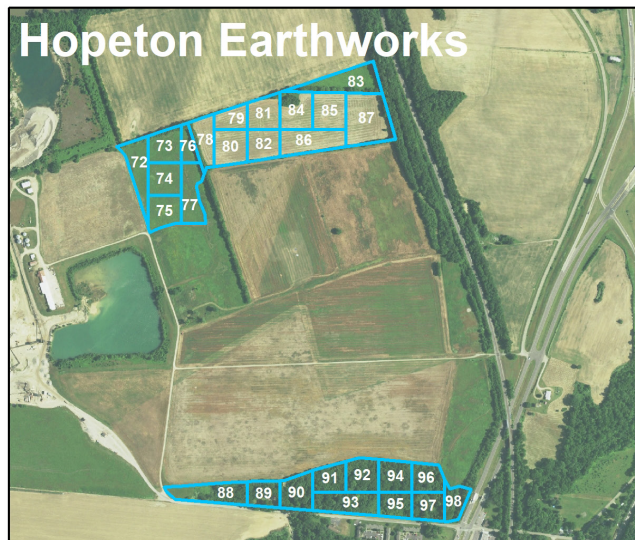
Table 2. Park-established problematic plant watch list used to guide surveys in Hopewell Culture NHP.

Scientific Name	Common Name
<i>Ailanthus altissima</i>	tree of heaven
<i>Albizia julibrissin</i>	silk tree
<i>Alliaria petiolata</i>	garlic mustard
<i>Arctium minus</i>	lesser burdock
<i>Berberis thunbergii</i>	Japanese barberry
<i>Bromus inermis</i>	smooth brome
<i>Bromus racemosus</i> *	bald brome, spiked brome
<i>Bromus sterilis</i>	poverty brome
<i>Bromus tectorum</i>	cheatgrass
<i>Celastrus orbiculatus</i>	Oriental bittersweet
<i>Cirsium arvense</i>	Canada thistle
<i>Cirsium vulgare</i>	bull thistle

* Searched for in 2011, 2015, and 2019 but not in 2008.

Table 2 (continued). Park-established problematic plant watch list used to guide surveys in Hopewell Culture NHP.

Scientific Name	Common Name
<i>Daucus carota</i>	Queen Anne's lace
<i>Dipsacus fullonum</i>	Fuller's teasel
<i>Elaeagnus umbellata</i>	autumn olive
<i>Euonymus alatus</i>	burningbush, winged euonymus
<i>Euonymus fortunei</i>	winter creeper
<i>Frangula alnus</i>	glossy buckthorn
<i>Glechoma hederacea</i>	ground ivy
<i>Hemerocallis fulva</i>	orange daylily
<i>Hesperis matronalis</i>	dames rocket
<i>Leonurus cardiaca</i>	common motherwort
<i>Ligustrum vulgare</i>	European privet
<i>Lonicera japonica</i>	Japanese honeysuckle
<i>Lonicera maackii</i>	Amur honeysuckle
<i>Lonicera morrowii</i>	Morrow's honeysuckle
<i>Lonicera shrub (maackii/morrowii/tatarica)</i>	bush honeysuckle sp. (Amur-Morrow's-Tatarian complex)
<i>Lonicera tatarica</i>	Tatarian honeysuckle
<i>Lysimachia nummularia</i>	creeping jenny
<i>Melilotus officinalis</i>	yellow sweetclover
<i>Microstegium vimineum</i>	Nepalese browntop, Japanese stiltgrass
<i>Morus alba</i>	white mulberry
<i>Pastinaca sativa</i>	wild parsnip
<i>Phalaris arundinacea</i>	reed canarygrass
<i>Poa compressa/pratensis</i>	Canada/Kentucky bluegrass complex
<i>Polygonum cuspidatum</i>	Japanese knotweed
<i>Poa pratensis</i>	Kentucky bluegrass
<i>Potentilla recta</i>	sulphur cinquefoil
<i>Prunus mahaleb</i>	Mahaleb cherry
<i>Pyrus calleryana</i>	Callery pear
<i>Rosa multiflora</i>	multiflora rose
<i>Robinia pseudoacacia</i>	black locust
<i>Rumex crispus</i>	curly dock
<i>Saponaria officinalis</i>	bouncingbet
<i>Schedonorus arundinaceus</i>	tall fescue
<i>Securigera varia</i>	crownvetch
<i>Sorghum halepense</i>	Johnsongrass
<i>Torilis arvensis</i>	spreading hedgeparsley
<i>Ulmus pumila</i>	Siberian elm
<i>Verbascum thapsus</i>	common mullein
<i>Vinca minor</i>	common periwinkle



 Search Units



Figure 1. Location of search units used to monitor problematic plants in Hopewell Culture NHP. Search unit size averaged 2.0 acres.

Analytical Methods

A park-wide cover range was estimated for each problematic plant species encountered during each year. First, we calculated the minimum and maximum fraction of the park observed. To do this we used an average search unit size of 2.1 acres (8,441.9 m²). The fraction of the park observed assuming a 3-m belt was calculated as 9.8%. The fraction of the park observed assuming a 12-m belt was calculated as 39.0%.

To calculate the minimum of the estimated cover range for each species, the lower endpoints associated with the assigned cover class values for that species were summed and then divided by the reference frame fraction observed assuming the widest possible (12 m) survey belt (i.e., maximum fraction observed; Equation 1).

Equation 1:

$$\text{Minimum cover estimate} = \frac{\sum \text{low end of cover value range for species}}{\text{fraction of park observed assuming 12-m (max) belt width}}$$

Maximum cover for each species was calculated similarly, summing the upper endpoints of the cover values in each occupied search unit and assuming that a 3-m belt was surveyed (i.e., minimum fraction of area observed; Equation 2).

Equation 2:

$$\text{Maximum cover estimate} = \frac{\sum \text{high end of cover value range for species}}{\text{fraction of park observed assuming 3-m (min) belt width}}$$

Cover values were then converted from square meters to acres by multiplying each value by 0.000247105.

The park-wide frequency of problematic plants was calculated as the percentage of occupied search units (Equation 3). We treated all search units as equivalent for the purposes of frequency calculations.

Equation 3:

$$\text{Frequency of a problematic plant species} = \frac{\sum \text{search units occupied by species}}{\sum \text{search units surveyed}} \times 100$$

Taken together, the minimum and maximum cover estimates provided an estimated range of cover that accounts for the uncertainty arising from the sampling method. Non-overlapping ranges represent the strongest evidence for differences in cover. In this study, we evaluated if the cover data collected in 2019 differed from any previous years based on non-overlapping cover ranges.

I-Ranks

The I-rank or invasive ranks are calculated using a standard protocol to assess the impacts of these plants (Morse et al. 2004). The I-ranks consist of four sub-ranks: ecological impact, current cover/distribution, trend in distribution/cover, and management difficulty. Because of their more direct implications for park management, the ecological impact and management difficulty sub-ranks, when available, were presented in the Results section (NatureServe 2018).

Taxonomic Notes

The Tartarian honeysuckle (*Lonicera tatarica*) identified in 2008 was not reidentified in subsequent surveys. We consider this species part of the bush honeysuckle (*L. maackii*/*L. morrowii*) complex for the purposes of this study. The annual brome species, bald brome (*Bromus racemosus*) and *B. tectorum* (cheatgrass), are also likely best interpreted as a group.

Results and Discussion

Plant cover and frequency estimates for the problematic plants encountered at Hopewell Culture NHP are presented in Table 3 and the 2019 data are depicted graphically using frequency and the midpoint of the cover range (Figure 2). In Figure 2 we grouped plants in four categories: (1) very low frequency (<2%, n = 7), (2) low frequency (>2–10%, n = 9), (3) medium frequency (>10–40%, n = 17), and (4) high frequency (>40%, n = 4). While many factors impact our ability to control problematic plants, we use 10 acres as a guideline to identify lower and higher probability chances for successful control. The cover midpoints of only two of the medium frequency species (autumn olive [*Elaeagnus umbellata*] and tall fescue [*Schedonorus umbellata*]) and two of the high frequency species (Japanese honeysuckle [*Lonicera japonica*] and amur honeysuckle [*Lonicera maackii*]) exceeded this threshold.

Across the monitoring record, Hopewell Culture NHP was found to support 51 problematic plant species. Several of these species are well-established

throughout much of the park. We found Amur honeysuckle, garlic mustard (*Alliaria petiolata*), Japanese honeysuckle, and multiflora rose (*Rosa multiflora*) in over half of the park's search units. These species are found primarily in woodlands and are somewhat naturally limited in the fields. Of these species, only amur honeysuckle is highly amenable to control efforts. The frequency of Japanese stiltgrass (*Microstegium vimineum*) has increased in the park from 0% in 2008 to 1.9% in 2011 to 10.3% in 2015 to 27.1% in 2019. Park managers should expect additional spread within forests and evaluate the impact of this invasive annual grass on park resources. Given the large number, extent, and cover of problematic plants in Hopewell Culture NHP, managers must strategically prioritize any control projects. These data continue to serve as early detection monitoring and provide a generalized understanding of problematic plant cover and distribution to support problematic plant management decisions.

Table 3. Cover and frequency of potentially problematic plants found in Hopewell Culture NHP. Ecological impact (EI) and general management difficulty (Mgmt) are based on NatureServe I-Rank sub-ranks (Morse et al. 2004; NatureServe 2018). Sub-ranks are given as high (H), medium (M), low (L), insignificant (I), a range of the above ranks, or not available (n/a). The assignment of “decrease in 2019” or “increase in 2019” next to a species indicates that the cover in 2019 for that species had decreased or increased relative to the noted year based on non-overlapping cover intervals.

ScientificName	CommonName	PeriodID	Low Cover Estimate (acres)	High Cover Estimate (acres)	Frequency	EI	Mgmt
<i>Ailanthus altissima</i>	tree of heaven	2011	0.0196	0.4024	3.7	ML	ML
<i>Ailanthus altissima</i>	tree of heaven	2015	0.0471	0.6125	10.3	ML	ML
<i>Ailanthus altissima</i>	tree of heaven	2019	0.0022	0.0840	6.5	ML	ML
<i>Albizia julibrissin</i>	silk tree	2015	0.0006	0.0250	0.9	ML	ML
<i>Alliaria petiolata</i>	garlic mustard	2008	0.4672	8.9949	53.3	ML	M
<i>Alliaria petiolata</i>	garlic mustard	2011	1.0340	14.7824	69.2	ML	M
<i>Alliaria petiolata</i>	garlic mustard	2015	0.0979	1.9882	60.7	ML	M
<i>Alliaria petiolata</i>	garlic mustard	2019	0.3444	7.1350	58.9	ML	M
<i>Arctium minus</i>	lesser burdock	2008	0.0007	0.0272	1.9	LI	MI
<i>Arctium minus</i>	lesser burdock	2011	0.0039	0.1520	6.5	LI	MI
<i>Berberis thunbergii</i>	Japanese barberry	2008	0.0026	0.1021	4.7	HM	I
<i>Berberis thunbergii</i>	Japanese barberry	2011	0.0222	0.5045	8.4	HM	I
<i>Berberis thunbergii</i>	Japanese barberry	2015	0.0015	0.0590	5.6	HM	I
<i>Berberis thunbergii</i>	Japanese barberry	2019	0.0068	0.2678	16.8	HM	I
<i>Bromus inermis</i>	smooth brome	2008	0.0196	0.5262	12.1	M	ML
<i>Bromus inermis</i>	smooth brome	2011	0.0963	1.9395	7.5	M	ML
<i>Bromus inermis</i>	smooth brome	2015	0.0400	0.4571	6.5	M	ML
<i>Bromus inermis</i>	smooth brome	2019	0.0279	0.6031	7.5	M	ML
<i>Bromus racemosus</i> *	bald brome, spiked brome	2011	0.0888	1.1332	15.0	n/a	n/a
<i>Bromus racemosus</i> *	bald brome, spiked brome	2015	0.1909	3.0565	7.5	n/a	n/a
<i>Bromus racemosus</i> *	bald brome, spiked brome	2019	0.1385	1.7239	21.5	n/a	n/a
<i>Bromus sterilis</i>	poverty brome	2011	0.0006	0.0250	0.9	ML	U
<i>Bromus tectorum</i>	cheatgrass	2008	0.0332	0.8119	18.7	H	HM
<i>Bromus tectorum</i>	cheatgrass	2011	0.5595	6.2502	20.6	H	HM

* Searched for in 2011, 2015, and 2019 but not in 2008.

Table 3 (continued). Cover and frequency of potentially problematic plants found in Hopewell Culture NHP. Ecological impact (EI) and general management difficulty (Mgmt) are based on NatureServe I-Rank sub-ranks (Morse et al. 2004; NatureServe 2018). Sub-ranks are given as high (H), medium (M), low (L), insignificant (I), a range of the above ranks, or not available (n/a). The assignment of “decrease in 2019” or “increase in 2019” next to a species indicates that the cover in 2019 for that species had decreased or increased relative to the noted year based on non-overlapping cover intervals.

ScientificName	CommonName	PeriodID	Low Cover Estimate (acres)	High Cover Estimate (acres)	Frequency	EI	Mgmt
<i>Celastrus orbiculatus</i>	Oriental bittersweet	2011	0.0070	0.1508	1.9	ML	M
<i>Celastrus orbiculatus</i> (increase in 2019)	Oriental bittersweet	2015	0.0001	0.0045	1.9	ML	M
<i>Celastrus orbiculatus</i>	Oriental bittersweet	2019	0.0078	0.1826	5.6	ML	M
<i>Cirsium arvense</i>	Canada thistle	2008	0.0355	0.9050	19.6	ML	HM
<i>Cirsium arvense</i> (decrease in 2019)	Canada thistle	2011	1.0036	14.7191	23.4	ML	HM
<i>Cirsium arvense</i>	Canada thistle	2015	0.1092	1.8230	9.3	ML	HM
<i>Cirsium arvense</i>	Canada thistle	2019	0.0204	0.4319	6.5	ML	HM
<i>Cirsium vulgare</i>	bull thistle	2008	0.0008	0.0318	3.7	ML	ML
<i>Cirsium vulgare</i>	bull thistle	2011	0.0013	0.0522	2.8	ML	ML
<i>Cirsium vulgare</i>	bull thistle	2015	0.0063	0.1258	0.9	ML	ML
<i>Cirsium vulgare</i>	bull thistle	2019	0.0004	0.0159	6.5	ML	ML
<i>Daucus carota</i>	Queen Anne's lace	2008	0.0373	1.2184	44.9	I	I
<i>Daucus carota</i>	Queen Anne's lace	2011	0.3264	5.6622	50.5	I	I
<i>Daucus carota</i>	Queen Anne's lace	2015	0.1134	1.7285	42.1	I	I
<i>Daucus carota</i>	Queen Anne's lace	2019	0.4303	7.5344	36.4	I	I
<i>Dipsacus fullonum</i>	Fuller's teasel	2008	0.0020	0.0772	3.7	L	ML
<i>Dipsacus fullonum</i>	Fuller's teasel	2011	0.0076	0.1757	2.8	L	ML
<i>Dipsacus fullonum</i>	Fuller's teasel	2015	0.0003	0.0113	4.7	L	ML
<i>Dipsacus fullonum</i>	Fuller's teasel	2019	0.0008	0.0295	2.8	L	ML
<i>Elaeagnus umbellata</i> (increase in 2019)	autumn olive	2008	0.2047	3.0956	30.8	H	L
<i>Elaeagnus umbellata</i>	autumn olive	2011	2.1802	43.3871	28.0	H	L
<i>Elaeagnus umbellata</i>	autumn olive	2015	0.9849	17.7547	33.6	H	L
<i>Elaeagnus umbellata</i>	autumn olive	2019	3.6252	61.9328	36.4	H	L

Table 3 (continued). Cover and frequency of potentially problematic plants found in Hopewell Culture NHP. Ecological impact (EI) and general management difficulty (Mgmt) are based on NatureServe I-Rank sub-ranks (Morse et al. 2004; NatureServe 2018). Sub-ranks are given as high (H), medium (M), low (L), insignificant (I), a range of the above ranks, or not available (n/a). The assignment of “decrease in 2019” or “increase in 2019” next to a species indicates that the cover in 2019 for that species had decreased or increased relative to the noted year based on non-overlapping cover intervals.

ScientificName	CommonName	PeriodID	Low Cover Estimate (acres)	High Cover Estimate (acres)	Frequency	EI	Mgmt
<i>Euonymus alatus</i>	burningbush, winged euonymus	2008	0.0028	0.1089	7.5	LI	L
<i>Euonymus alatus</i>	burningbush, winged euonymus	2011	0.0076	0.1757	2.8	LI	L
<i>Euonymus alatus</i>	burningbush, winged euonymus	2015	0.0032	0.1225	13.1	LI	L
<i>Euonymus alatus</i>	burningbush, winged euonymus	2019	0.0049	0.1929	14.0	LI	L
<i>Euonymus fortunei</i>	winter creeper	2015	0.0015	0.0590	5.6	M	LI
<i>Euonymus fortunei</i>	winter creeper	2019	0.0183	0.4718	17.8	M	LI
<i>Frangula alnus</i>	glossy buckthorn	2015	0.0007	0.0272	1.9	HL	M
<i>Frangula alnus</i>	glossy buckthorn	2019	0.0001	0.0045	1.9	HL	M
<i>Glechoma hederacea</i>	ground ivy	2008	0.3112	4.9358	32.7	MI	U
<i>Glechoma hederacea</i>	ground ivy	2011	2.0750	33.1459	43.0	MI	U
<i>Glechoma hederacea</i>	ground ivy	2015	0.2493	4.3649	27.1	MI	U
<i>Glechoma hederacea</i>	ground ivy	2019	0.4832	8.6295	33.6	MI	U
<i>Hemerocallis fulva</i>	orange daylily	2008	0.0038	0.1498	5.6	MI	L
<i>Hemerocallis fulva</i>	orange daylily	2011	0.0006	0.0250	0.9	MI	L
<i>Hemerocallis fulva</i>	orange daylily	2015	0.0039	0.1520	6.5	MI	L
<i>Hesperis matronalis</i>	dames rocket	2008	0.0032	0.1248	4.7	MI	HL
<i>Hesperis matronalis</i>	dames rocket	2015	0.0001	0.0023	0.9	MI	HL
<i>Leonurus cardiaca</i>	common motherwort	2008	0.0001	0.0023	0.9	n/a	n/a
<i>Ligustrum vulgare</i>	European privet	2008	0.0040	0.1566	8.4	HL	HM
<i>Ligustrum vulgare</i>	European privet	2011	0.0515	1.1621	19.6	HL	HM
<i>Ligustrum vulgare</i>	European privet	2015	0.0067	0.2587	22.4	HL	HM
<i>Ligustrum vulgare</i>	European privet	2019	0.0259	0.6430	28.0	HL	HM

Table 3 (continued). Cover and frequency of potentially problematic plants found in Hopewell Culture NHP. Ecological impact (EI) and general management difficulty (Mgmt) are based on NatureServe I-Rank sub-ranks (Morse et al. 2004; NatureServe 2018). Sub-ranks are given as high (H), medium (M), low (L), insignificant (I), a range of the above ranks, or not available (n/a). The assignment of “decrease in 2019” or “increase in 2019” next to a species indicates that the cover in 2019 for that species had decreased or increased relative to the noted year based on non-overlapping cover intervals.

ScientificName	CommonName	PeriodID	Low Cover Estimate (acres)	High Cover Estimate (acres)	Frequency	EI	Mgmt
<i>Lonicera japonica</i>	Japanese honeysuckle	2008	0.7566	10.4278	59.8	M	HM
<i>Lonicera japonica</i>	Japanese honeysuckle	2011	6.2449	103.2611	78.5	M	HM
<i>Lonicera japonica</i>	Japanese honeysuckle	2015	1.4257	25.5761	72.0	M	HM
<i>Lonicera japonica</i>	Japanese honeysuckle	2019	2.1663	37.2750	65.4	M	HM
<i>Lonicera maackii</i> (increase in 2019)	Amur honeysuckle	2008	0.3791	6.1176	63.6	HM	M
<i>Lonicera maackii</i>	Amur honeysuckle	2011	7.1774	119.4470	76.6	HM	M
<i>Lonicera maackii</i>	Amur honeysuckle	2015	4.3958	55.1458	71.0	HM	M
<i>Lonicera maackii</i>	Amur honeysuckle	2019	9.1882	149.6657	81.3	HM	M
<i>Lonicera morrowii</i> (decrease in 2019)	Morrow's honeysuckle	2011	0.8889	13.1815	21.5	ML	M
<i>Lonicera morrowii</i>	Morrow's honeysuckle	2015	0.0231	0.5363	12.1	ML	M
<i>Lonicera morrowii</i>	Morrow's honeysuckle	2019	0.0084	0.2052	5.6	ML	M
<i>Lonicera shrub (maackii/ morrowii/tatarica)</i>	bush honeysuckle sp. (Amur- Morrow's-Tatarian complex)	2011	0.0006	0.0250	0.9	M	M
<i>Lonicera tatarica</i>	Tatarian honeysuckle	2008	0.0279	0.8530	25.2	M	M
<i>Lysimachia nummularia</i>	creeping jenny	2008	0.0146	0.5741	21.5	L	L
<i>Lysimachia nummularia</i>	creeping jenny	2011	0.4296	6.7482	34.6	L	L
<i>Lysimachia nummularia</i>	creeping jenny	2015	0.0239	0.5681	15.9	L	L
<i>Lysimachia nummularia</i>	creeping jenny	2019	0.0477	1.1362	22.4	L	L
<i>Melilotus officinalis</i> (decrease in 2019)	yellow sweetclover	2008	0.0080	0.3132	16.8	M	M
<i>Melilotus officinalis</i>	yellow sweetclover	2011	0.0191	0.5035	12.1	M	M
<i>Melilotus officinalis</i>	yellow sweetclover	2015	0.0001	0.0023	0.9	M	M
<i>Melilotus officinalis</i>	yellow sweetclover	2019	0.0001	0.0045	1.9	M	M

Table 3 (continued). Cover and frequency of potentially problematic plants found in Hopewell Culture NHP. Ecological impact (EI) and general management difficulty (Mgmt) are based on NatureServe I-Rank sub-ranks (Morse et al. 2004; NatureServe 2018). Sub-ranks are given as high (H), medium (M), low (L), insignificant (I), a range of the above ranks, or not available (n/a). The assignment of “decrease in 2019” or “increase in 2019” next to a species indicates that the cover in 2019 for that species had decreased or increased relative to the noted year based on non-overlapping cover intervals.

ScientificName	CommonName	PeriodID	Low Cover Estimate (acres)	High Cover Estimate (acres)	Frequency	EI	Mgmt
<i>Microstegium vimineum</i>	Nepalese browntop, Japanese stiltgrass	2011	0.0380	0.3777	1.9	M	HM
<i>Microstegium vimineum</i>	Nepalese browntop, Japanese stiltgrass	2015	0.0674	0.6604	10.3	M	HM
<i>Microstegium vimineum</i>	Nepalese browntop, Japanese stiltgrass	2019	0.1797	2.9832	27.1	M	HM
<i>Morus alba</i>	white mulberry	2008	0.0393	0.9287	15.9	ML	ML
<i>Morus alba</i>	white mulberry	2011	0.3948	6.7555	16.8	ML	ML
<i>Morus alba</i>	white mulberry	2015	0.6251	7.9764	24.3	ML	ML
<i>Morus alba</i>	white mulberry	2019	0.1543	2.7310	17.8	ML	ML
<i>Pastinaca sativa</i>	wild parsnip	2008	0.0024	0.0930	10.3	LI	L
<i>Pastinaca sativa</i>	wild parsnip	2011	0.0419	0.5298	8.4	LI	L
<i>Pastinaca sativa</i>	wild parsnip	2015	0.0154	0.3583	8.4	LI	L
<i>Pastinaca sativa</i>	wild parsnip	2019	0.0326	0.6654	10.3	LI	L
<i>Phalaris arundinacea</i>	reed canarygrass	2008	0.0027	0.1044	5.6	H	HM
<i>Phalaris arundinacea</i>	reed canarygrass	2011	0.0082	0.2007	3.7	H	HM
<i>Phalaris arundinacea</i>	reed canarygrass	2015	0.0006	0.0250	0.9	H	HM
<i>Poa compressa/pratensis</i>	Canada/Kentucky bluegrass complex	2011	0.0862	1.9093	26.2	M	M
<i>Poa compressa/pratensis</i>	Canada/Kentucky bluegrass complex	2015	0.0674	1.4148	17.8	M	M
<i>Poa compressa/pratensis</i>	Canada/Kentucky bluegrass complex	2019	0.3086	3.9509	29.0	M	M
<i>Poa pratensis</i> (decrease in 2019)	Kentucky bluegrass	2008	0.0199	0.6591	24.3	M	ML
<i>Poa pratensis</i>	Kentucky bluegrass	2019	0.0001	0.0023	0.9	M	ML
<i>Polygonum cuspidatum</i>	Japanese knotweed	2011	0.0063	0.1258	0.9	HM	M
<i>Polygonum cuspidatum</i>	Japanese knotweed	2015	0.0006	0.0250	0.9	HM	M

Table 3 (continued). Cover and frequency of potentially problematic plants found in Hopewell Culture NHP. Ecological impact (EI) and general management difficulty (Mgmt) are based on NatureServe I-Rank sub-ranks (Morse et al. 2004; NatureServe 2018). Sub-ranks are given as high (H), medium (M), low (L), insignificant (I), a range of the above ranks, or not available (n/a). The assignment of “decrease in 2019” or “increase in 2019” next to a species indicates that the cover in 2019 for that species had decreased or increased relative to the noted year based on non-overlapping cover intervals.

ScientificName	CommonName	PeriodID	Low Cover Estimate (acres)	High Cover Estimate (acres)	Frequency	EI	Mgmt
<i>Potentilla recta</i>	sulphur cinquefoil	2008	0.0023	0.0908	9.3	HL	ML
<i>Potentilla recta</i>	sulphur cinquefoil	2011	0.0020	0.0772	3.7	HL	ML
<i>Prunus mahaleb</i>	Mahaleb cherry	2008	0.0006	0.0250	0.9	LI	U
<i>Pyrus calleryana</i> (decrease in 2019)	Callery pear	2011	0.0063	0.1258	0.9	LI	ML
<i>Pyrus calleryana</i>	Callery pear	2015	0.0001	0.0023	0.9	LI	ML
<i>Pyrus calleryana</i>	Callery pear	2019	0.0001	0.0045	1.9	LI	ML
<i>Robinia pseudoacacia</i>	black locust	2008	0.1210	2.1622	23.4	HM	M
<i>Robinia pseudoacacia</i>	black locust	2011	0.9555	12.2990	30.8	HM	M
<i>Robinia pseudoacacia</i>	black locust	2015	0.7878	10.4162	18.7	HM	M
<i>Robinia pseudoacacia</i>	black locust	2019	0.3330	4.7974	22.4	HM	M
<i>Rosa multiflora</i>	multiflora rose	2008	0.3589	4.9358	60.7	L	L
<i>Rosa multiflora</i>	multiflora rose	2011	1.8051	29.7101	67.3	L	L
<i>Rosa multiflora</i>	multiflora rose	2015	0.5015	8.3423	60.7	L	L
<i>Rosa multiflora</i>	multiflora rose	2019	0.3791	6.3710	58.9	L	L
<i>Rumex crispus</i>	curly dock	2008	0.0058	0.2269	18.7	LI	ML
<i>Rumex crispus</i>	curly dock	2011	0.0299	0.9302	29.0	LI	ML
<i>Rumex crispus</i>	curly dock	2015	0.0027	0.1067	6.5	LI	ML
<i>Rumex crispus</i>	curly dock	2019	0.0020	0.0772	13.1	LI	ML
<i>Saponaria officinalis</i>	bouncingbet	2011	0.0139	0.3016	3.7	I	U
<i>Saponaria officinalis</i>	bouncingbet	2015	0.0006	0.0250	0.9	I	U
<i>Saponaria officinalis</i>	bouncingbet	2019	0.0007	0.0272	1.9	I	U
<i>Schedonorus arundinaceus</i>	tall fescue	2011	4.3231	78.6056	61.7	M	HM
<i>Schedonorus arundinaceus</i>	tall fescue	2015	0.9620	13.5656	28.0	M	HM
<i>Schedonorus arundinaceus</i>	tall fescue	2019	1.2775	20.5725	38.3	M	HM
<i>Securigera varia</i>	crownvetch	2015	0.0006	0.0250	0.9	H	L
<i>Securigera varia</i>	crownvetch	2019	0.0006	0.0250	0.9	H	L

Table 3 (continued). Cover and frequency of potentially problematic plants found in Hopewell Culture NHP. Ecological impact (EI) and general management difficulty (Mgmt) are based on NatureServe I-Rank sub-ranks (Morse et al. 2004; NatureServe 2018). Sub-ranks are given as high (H), medium (M), low (L), insignificant (I), a range of the above ranks, or not available (n/a). The assignment of “decrease in 2019” or “increase in 2019” next to a species indicates that the cover in 2019 for that species had decreased or increased relative to the noted year based on non-overlapping cover intervals.

ScientificName	CommonName	PeriodID	Low Cover Estimate (acres)	High Cover Estimate (acres)	Frequency	EI	Mgmt
<i>Sorghum halepense</i> (increase in 2019)	Johnsongrass	2008	0.0065	0.2564	12.1	ML	HM
<i>Sorghum halepense</i>	Johnsongrass	2011	0.4613	8.8953	20.6	ML	HM
<i>Sorghum halepense</i>	Johnsongrass	2015	0.1831	3.7499	26.2	ML	HM
<i>Sorghum halepense</i>	Johnsongrass	2019	0.5920	7.7916	27.1	ML	HM
<i>Torilis arvensis</i>	spreading hedgeparsley	2008	0.0121	0.4766	18.7	n/a	n/a
<i>Torilis arvensis</i>	spreading hedgeparsley	2011	0.0412	1.0058	19.6	n/a	n/a
<i>Torilis arvensis</i>	spreading hedgeparsley	2015	0.0015	0.0567	4.7	n/a	n/a
<i>Torilis arvensis</i>	spreading hedgeparsley	2019	0.0454	0.5421	9.3	n/a	n/a
<i>Ulmus pumila</i>	Siberian elm	2011	0.0001	0.0023	0.9	ML	ML
<i>Ulmus pumila</i>	Siberian elm	2015	0.0003	0.0113	4.7	ML	ML
<i>Verbascum thapsus</i>	common mullein	2008	0.0001	0.0045	1.9	ML	L
<i>Verbascum thapsus</i> (decrease in 2019)	common mullein	2011	0.0025	0.0999	3.7	ML	L
<i>Verbascum thapsus</i>	common mullein	2015	0.0016	0.0613	6.5	ML	L
<i>Verbascum thapsus</i>	common mullein	2019	0.0001	0.0023	0.9	ML	L
<i>Vinca minor</i>	common periwinkle	2008	0.0526	0.7042	6.5	I	U
<i>Vinca minor</i>	common periwinkle	2011	1.9743	39.3575	10.3	I	U
<i>Vinca minor</i>	common periwinkle	2015	0.5519	6.8312	7.5	I	U
<i>Vinca minor</i>	common periwinkle	2019	0.5457	6.7099	8.4	I	U

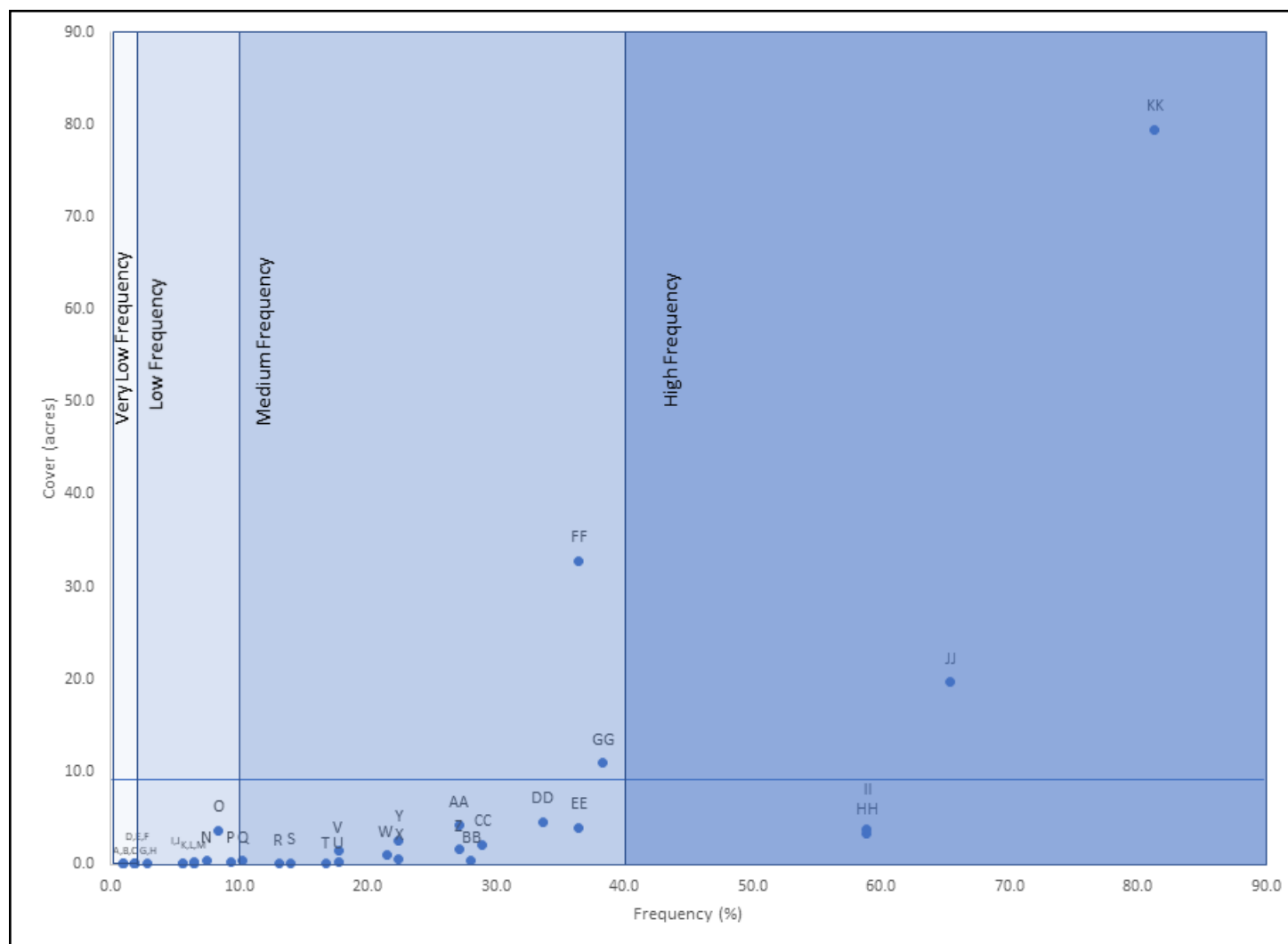


Figure 2. Problematic plant cover and frequency relationship in 2019 at Hopewell Culture NHP. The cover measure used is based on the midpoint of the cover range. Plants are categorized into four categories: very low frequency (<2%), low frequency (>2–10%), medium frequency (>10–40%) and high frequency (>40%). The horizontal line marks the 10-acre threshold at which successful control of a plant becomes less likely. Species in ascending order of frequency include A) *Poa pratensis*, B) *Securigera varia*, C) *Verbascum thapsus*, D) *Frangula alnus*, E) *Melilotus officinalis*, F) *Pyrus calleryana*, G) *Saponaria officinalis*, H) *Dipsacus fullonum*, I) *Celastrus orbiculatus*, J) *Lonicera morrowii*, K) *Ailanthus altissima*, L) *Cirsium arvense*, M) *Cirsium vulgare*, N) *Bromus inermis*, O) *Vinca minor*, P) *Torilis arvensis*, Q) *Pastinaca sativa*, R) *Rumex crispus*, S) *Euonymus alatus*, T) *Berberis thunbergii*, U) *Euonymus fortunei*, V) *Morus alba*, W) *Bromus racemosus*, X) *Lysimachia nummularia*, Y) *Robinia pseudoacacia*, Z) *Microstegium vimineum*, AA) *Sorghum halepense*, BB) *Ligustrum vulgare*, CC) *Poa compressa/pratensis*, DD) *Glechoma hederacea*, EE) *Daucus carota*, FF) *Elaeagnus umbellata*, GG) *Schedonorus arundinaceus*, HH) *Alliaria petiolata*, II) *Rosa multiflora*, JJ) *Lonicera japonica*, and KK) *Lonicera maackii*.

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