National Park Service
U.S. Department of the Interior

Northeast Region
Philadelphia, Pennsylvania

Statistical Analysis of Understory Vegetation Data from Valley Forge National Historical Park, Pennsylvania, 1993–2003

Technical Report NPS/NER/NRTR—2008/118

ON THE COVER
Control (top right) and exclosure (bottom left) of site 6 on Mount Misery in 2006.
Photographs courtesy of Mark Bowermaster and Ashley Fieger.

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April 2008

U.S. Department of the Interior
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Northeast Region
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This report was accomplished under Cooperative Agreement H4560030064, Task Agreement No. 023 with assistance from the NPS. The statements, findings, conclusions, recommendations, and data in this report are solely those of the author(s), and do not necessarily reflect the views of the U.S. Department of the Interior, National Park Service.

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Please cite this publication as:

Diefenbach, D., W. Vreeland, and K. M. Heister. 2008. Statistical Analysis of Understory Vegetation Data from Valley Forge National Historical Park, Pennsylvania, 1993–2003. Technical Report NPS/NER/NRTR—2008/118. National Park Service. Philadelphia, PA.

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Executive Summary

A fixed-plot monitoring system was implemented in 1992 to evaluate vegetative communities in two large wooded areas at Valley Forge National Historical Park. The objectives of this monitoring system are to: 1) describe the existing understory plant community on Mount Misery and Mount Joy in terms of species richness and abundance; and 2) determine changes in abundance and species composition of understory plant communities in fenced and unfenced plots over time. This report summarizes the data collected in these plots in 1993, 1995–1996, 1998, and 2003, and presents the results of statistical analyses of the data to determine if specific vegetative changes have occurred over time.

Thirty vegetation sample sites were randomly located on Mount Misery and Mount Joy (15 in each area). At each sample site, paired plots were established where one plot was fenced to exclude deer but no other herbivores. The unfenced control plots were located 36.5 m (119.75 ft) from the center of the fenced plots in a random direction (except three plots were located 20–27.4 m [65.6–90 ft] away). Each plot was 2×2 m (6.5×6.5 ft) in size. Most tree, shrub, vine, and herbaceous vegetation was identified to species, although some vegetation was identified only to genera. The number of tree seedlings was enumerated in all plots.

Species richness was greater on Mount Joy than on Mount Misery for each of the years, and in both areas generally increased over time in fenced plots and exhibited a slight decline over time in unfenced plots. Between 1993 and 2003 on Mount Misery, the total number of species increased from 31 to 41 species in fenced plots, and decreased from 27 to 23 species in unfenced plots. On Mount Joy, the total number of species increased from 56 to 71 species in fenced plots and declined from 51 to 48 species in unfenced plots. On average, only 28% of species that were present in the fenced plots (mean no. species = 10.4) were present in the unfenced plots.

Over all years, the number of fenced and unfenced plots containing exotic species exhibited similar changes observed for overall species richness. In general, exotic species were present in more fenced plots than in unfenced plots and individual fenced plots contained more exotic species than did individual unfenced plots. Twenty-two of the 24 exotic species recorded from plots have been present in at least one fenced plot during one or more of the four sampling periods. Since 1995, two species were first observed in fenced plots in 1998 and two species were first observed in fenced plots in 2003. The overall increase in the number of exotic species in plots between 1993 and 2003 is due solely to an increase observed in fenced plots on Mount Joy (from 78 to 95 [number of species occurrences per plot summed over all the plots]).

Mean tree seedling counts in 2003 were greater in fenced plots, but the large variability in seedling counts among plots precluded any statistically significant evidence of a change over time or differences between Mount Joy and Mount Misery. By 2003, there were, on average, 7.1 (SE=1.56) and 11.3 (SE=1.54) more species of tree seedlings in fenced plots than in unfenced plots on Mount Misery and Mount Joy, respectively.

Guidelines for acceptable abundance of tree seedlings for forest regeneration are 25 seedlings per 12.57 m^2 (135 ft^2 [McWilliams et al. 2002]). The percentage of plots with adequate seedling abundance is referred to as a stocking rate. We calculated stocking rates using all tree species

combined, only native tree species, and only deer-preferred tree species. When either exotic tree species or species that deer do not prefer are excluded from the calculations there was minimal effect on stocking rates. In 1993, three percent of both unfenced and fenced plots had adequate seedling abundance. However, by 2003 the stocking rate in fenced and unfenced plots was 27% and 0%, respectively.

In 2003, four (Jack-in-the-pulpit [*Arisaema triphyllum*], wild sarsaparilla [*Aralia nudicaulis*], sweet cicely [*Osmorhiza claytoni*], and Indian cucumber root [*Medeola virginiana*]) of six herbaceous species known to occur in the park that have been proposed as potential indicator species of the effects of deer browsing (Latham et al. 2005) occurred in nine of 30 fenced plots (1–3 species present per plot), and one species (Jack-in-the-pulpit) was present in six of 30 unfenced plots. Whenever Jack-in-the-pulpit was present in an unfenced plot, it also occurred in the paired fenced plot.

Acknowledgments

We thank Margaret A. Carfioli for assistance with explaining the data collection methods and providing assistance with use of the database. Also, we thank the National Park Service for letting us use contents from the report on the analysis of 1993–1998 data vegetation.

Introduction

A fixed-plot monitoring system (Storm and Ross 1992) was implemented in 1992 to evaluate vegetative communities in two large wooded areas at Valley Forge National Historical Park. The objectives of this monitoring system are to:

1. Describe the existing understory plant community on Mount Misery and Mount Joy in terms of species richness and abundance; and

2. Determine changes in abundance and species composition of understory plant communities in fenced and unfenced plots over time.

Data collected at four time periods (1993, 1995–1996, 1998, and 2003) as part of this monitoring program were provided in a Microsoft Access database. We analyzed these data to statistically test if changes in the vegetation occurred over time.

Study Area

Regional Information

Valley Forge National Historical Park is located 20 km (12.4 mi) northwest of Philadelphia, Pennsylvania in Chester and Montgomery counties, within the Upland Piedmont Plateau ecological region in southeastern Pennsylvania (Keys et al. 1995). The park consists of 1,403 ha (3,466 ac). It is located just south of Braun's (1950) boundary between the Glaciated and Piedmont sections of the Oak-Chestnut Forest Region, which also approximates the boundary between the Lowland and Upland U.S. Forest Service subsections of the Piedmont (Kasmer et al. 1994; Keys et al. 1995). The area has a long history of human impacts from forest clearing for encampment during the Revolutionary War (1777–1778), agriculture, industrial use, and development. All of these factors, in addition to the bedrock geology, soil composition, and site-specific characteristics, such as slope, aspect, and moisture regime, influence the current-day vegetation patterns at Valley Forge NHP (Podniesinski et al. 2005).

Park-specific Information

The two largest contiguous park woodlands, Mount Misery and Mount Joy, were selected as sample polygons. Large sections of each polygon bordering Valley Creek have slopes >15 degrees and were excluded from the sampling polygon. Mount Misery borders Valley Creek to the west and encompasses approximately 93 ha (229 ac). Mount Joy borders Valley Creek to the east and encompasses approximately 94 ha (233 ac).

Vegetation

The predominant existing forest communities at Valley Forge National Historical Park include a Dry Oak Forest that occurs primarily on ridges and slopes of Mount Misery and Mount Joy, and a Successional Tuliptree Forest that occurs on the lower slopes and flat terrain. The Dry Oak community covers approximately 158 ha (390 ac) and the Successional Tuliptree community covers approximately 151 ha (374 ac) of the park (Davis et al. 2006).

The Dry Oak Forest type is most common on the slopes of Mount Joy and Mount Misery within the park. The canopy is dominated by drought-tolerant chestnut oak (*Quercus prinus*) and black oak (*Quercus veluntina*) with blackgum (*Nyssa sylvatica*) and scarlet oak (*Quercus coccinea*) as occasional codominants. The subcanopy is characterized by moderate to dense cover of blackgum, red maple (*Acer rubrum*), and sassafras (*Sassafras albidum*). The tall shrub layer is often diagnostic for this type, characterized by moderate to dense cover of mountain laurel (*Kalmia latifolia*). In some stands, the tall-shrub layer is dominated by young blackgum. Also common in the tall-shrub layer are red maple, sassafras, and witch-hazel (*Hamamelis virginiana*). The low-shrub and herbaceous layers are typically very sparse or absent, presumably due to heavy deer browse. The low-shrub layer, when present, is limited to seedlings of canopy trees and a few ericaceous species: early lowbush blueberry (*Vaccinium pallidum*), black huckleberry (*Gaylussacia baccata*), and pink azalea (*Rhododendron periclymenoides*). Herbaceous plants typically occur as solitary individuals or small clumps, when present. Common herbaceous species include striped pipsissewa (*Chimaphila maculata*),

hay-scented fern (*Dennstaedtia punctilobula*), marginal woodfern (*Dryopteris marginalis*), and Indian cucumber-root (*Medeola virginiana*).

The mesic variant of the Dry Oak Forest (Podniesinski et al. 2005) occurs on moderate slopes with slightly more mesic soils than is found on the upper slopes. Canopy dominants are dry-site oaks (chestnut oak, black oak, and scarlet oak), but the canopy also includes a greater proportion of other hardwood species, including white oak (*Quercus alba*), red maple, tuliptree (*Lirodendron tulipifera*), American beech (*Fagus grandifolia*), and sassafras. A subcanopy is usually present, characterized by a mix of hardwood species such as red maple, sassafras, American beech, chestnut oak, and black oak. Typical tall shrubs include flowering dogwood (*Cornus florida*), witch-hazel, and mountain laurel. The tall-shrub layer varies from sparse to abundant, with flowering dogwood exceeding 50% cover in some locations. The low-shrub and herbaceous layers are very sparse to nearly absent, presumably the result of intense deer browse. The low-shrub layer is characterized by seedlings of the canopy and subcanopy woody species. Typical herbaceous species include garlic mustard (*Alliaria petiolata*), Japanese stiltgrass (*Microstegium vimineum*), and Pennsylvania sedge (*Carex pensylvanica*).

The Successional Tuliptree Forest community occurs throughout the park on a variety of substrates and soil types. This forest community occurs as mid-successional and mature forest stands. Some of these stands were planted 70 to 80 years ago. The most characteristic feature of this community type is the dominance of tuliptree. Tuliptree is the only dominant in many stands, with black oak and white ash (*Fraxinus americana*) codominant or subdominant in others. Other occasional canopy trees include red maple, northern red oak, and sassafras. The subcanopy is usually open (typically less than 30% total cover, though may approach 50%), characterized by tuliptree, red maple, tall individuals of flowering dogwood, blackgum, occasional redbud (*Cercis canadensis*), and sassafras. The shrub layer is also open and appears to be pruned below 1.5 m (5 ft) by heavy deer browse. Typical shrub species are flowering dogwood (clear dominant in the shrub layer), northern spicebush (*Lindera benzoin*), mountain laurel, and the nonnative Japanese honeysuckle (*Lonicera japonica*). Smooth blackhaw (*Viburnum prunifolium*) also occurs sporadically. The herbaceous layer has very low diversity and is dominated by exotics, including Japanese stiltgrass, except in stands with a very dense canopy, in which case there may be a high proportion of bare ground. Other herbaceous associates in addition to Japanese stiltgrass include garlic mustard, Oriental lady's-thumb (*Polygonum caespitosum*), Jack-in-the-pulpit (*Arisaema triphyllum*), and Canadian clearweed (*Pilea pumila*). Characteristic species that occur in the Successional Tuliptree Forest community, and that do not typically occur in the oak forests, include hairy Solomon's-seal (*Polygonatum pubescens*), Maryland black snakeroot (*Sanicula marilandica*), and alpine enchanter's nightshade (*Circaea alpina*).

Substrate

Mount Misery consists of the Cambrian Age Chickies Formation, a very hard, erosion-resistant rock composed of quartzite and quartz schist. Dry Oak Forests dominated by chestnut oak, black oak, northern red oak, and white oak are common on these acidic, well-drained, rocky Edgemont soils occurring on upper slopes (USDA SCS 1967). The infertile soils and the steep terrain on Mount Misery were likely unsuitable for farming historically. The forests on this ridge were used as woodlots for charcoal production (Rhoads et al. 1989).

Mount Joy occurs on the slightly younger Cambrian Age Antietam and Harpers (undivided) formations. These rock types are composed of quartzite, schist, and phyllite, and are fairly erosion resistant. Edgemont stony loam soils derived from these formations can be somewhat calcareous and are slightly more mesic than soils that occur on the Chickies Quartzite Formation (Pennsylvania Geological Survey 1981; Pennsylvania Bureau of Topographic and Geographic Survey 2001; Podniesinski et al. 2005). These moderate slopes may have been better suited for farming historically than the steeper slopes and rockier soils of Mount Misery (Rhoads et al. 1989). The Successional Tuliptree community is common on these substrates as well as those derived from the Triassic Stockton Formation.

Methods

Plot Selection

Thirty vegetation sample sites were located on Mount Misery and Mount Joy (15 in each area). These vegetation sample sites were selected randomly by overlaying a grid (cell size = 36.5 m^2 [383.2 ft^2]) on a map of the study area. Grid intersections (representing the center of each potential sample site) were randomly selected as sample sites. If a selected sample site was located on a trail, road, park boundary, or had a slope of >50%, another site was randomly selected.

A 3×3 m (9.8×9.8 ft) fenced area was established with its center at each randomly located grid intersection in May and June 1992 (Figure 1). The boundaries of fenced vegetation areas were oriented along cardinal directions. The corners of each fenced area were marked with galvanized metal posts (2 m [6.5 ft] in height), and metal fencing (12.5 gauge, 2 m [6.5 ft] in height) was secured to the posts with aluminum ties. Fencing mesh size was 5×10 cm (1.96×3.94 in) to allow entry of small rodents such as eastern gray squirrel (*Sciurus carolinensis*), eastern chipmunk (*Tamias striatus*), and cottontail rabbits (*Sylvilagus floridanus*), but exclude white-tailed deer (*Odocoileus virginianus*). A 2×2 m (6.5×6.5 ft) plot centered within the fenced area was used for vegetation sampling.

The centers of thirty 2×2 m (6.5×6.5 ft) unfenced control plots (15 in each area) were located 36.5 m (383.2 ft [one grid cell]) from fenced plot centers in a randomly selected cardinal direction. Unfenced plots were selected based on the similarity of ecological attributes (soil type, aspect, slope, geological substrate, hydrologic features, and forest type) to the corresponding fenced plot to provide matched, paired plots. Ninety percent (n=27) of unfenced plots were established 36.5 m (383.2 ft) from fenced plot centers. The remaining unfenced plots (n=3) were established 20–27.4 m (65.6–89.9 ft) from the center of the corresponding fenced plot in order to maintain a similarity of ecological attributes. The center of each unfenced plot was marked with a galvanized metal post (2 m [6.5 ft] in height).

Vegetation Sampling

Plots were sampled in 1993, 1995–96, 1998, and 2003; however, because most data from the 1995–96 sampling period occurred in 1995, we treated data from plots sampled in 1996 as if they were sampled in 1995. The vegetative community in the 3×3 m (9.8×9.8 ft) fenced areas was measured within a central 2×2 m (6.5×6.5 ft) plot delineated with a 4-m^2 (43-ft^2) PVC frame. Walking within fenced sites was restricted to the buffer surrounding the area sampled. Vegetation sampling of unfenced plots was similarly restricted to the 2×2 m (6.5×6.5 ft) area surrounding the metal center post. The PVC frame was oriented along cardinal directions with the post of the unfenced plot in the center of the frame.

The classification of vegetative species as herbaceous, vine, or shrub was based on Rhoads and Klein (1993). In 2003, additional references were used to confirm species classifications and update taxonomy: Pennsylvania Flora Project database (http://www.paflora.org/), U.S. Department of Agriculture PLANTS database (http://plants.usda.gov/index.html), and the U.S. Department of Agriculture ITIS database (http://www.itis.usda.gov/advanced_search.html). Tree

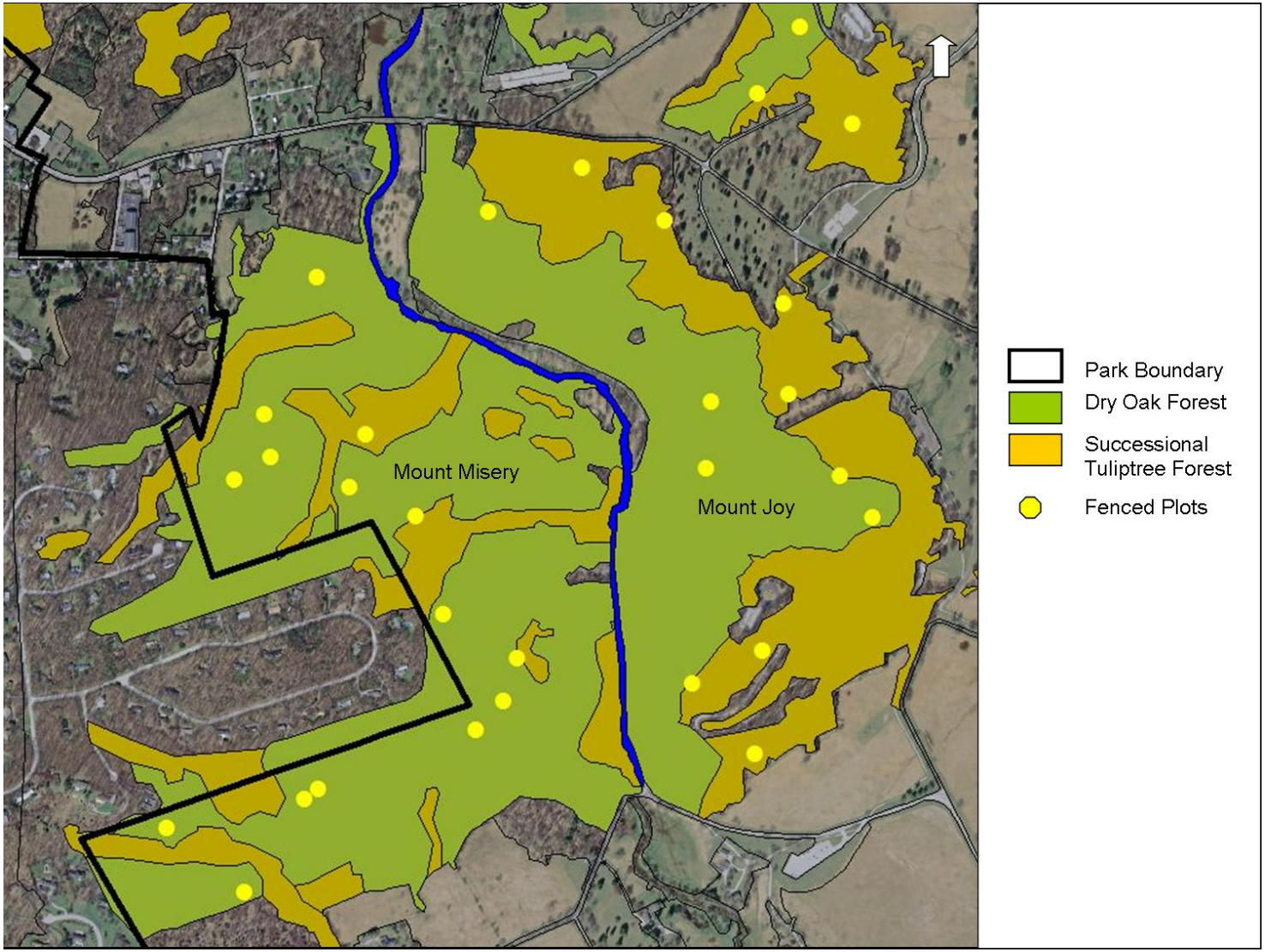

Figure 1. Location of fenced monitoring plots with in Dry Oak Forest and Successional Tuliptree Forest types on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania.

seedlings were classified as stems ≤ 150 cm (60 in) in height. Measurement of vegetation followed as closely as possible protocols developed by Storm and Ross (1992) for monitoring vegetation on public lands in Mid-Atlantic States. However, changes in protocols occurred over the years because of time and personnel constraints.

Herbaceous, Shrub, and Vine Cover: 1993 and 1995

Herbaceous vegetation, shrubs, and vines were typically identified to species, and minimally to genus. For each species, a visual estimate of percent cover within a plot was recorded in the following classes: 1=0–4%; 2=5–25%; 3=26–50%; 4=51–75%; 5=76–95%; and 6=96–100%. Vegetation was not stratified by height.

Herbaceous, Shrub, and Vine Cover: 1998

Data were collected as in 1993 and 1995. In addition, each 2×2 m (6.5×6.5 ft) plot was divided into four 1×1 m (3.25×3.25 ft) quadrants in 1998 and at the center of each quadrant mean height of all herbaceous, shrub, and vine species combined was estimated. A visual estimate of percent vegetation cover (all herbaceous, shrub, and vine species combined) within each 2×2 m (6.5×6.5 ft) sample plot also was recorded. All plants in 1998 were identified to species.

Herbaceous, Shrub, and Vine Cover: 2003

Data were collected as in 1993 and 1995. In addition, when it was easy to determine that shrub stems were present within one height class, the height class of shrubs was recorded using the same height classes used for tree seedlings (1=0–25 cm, 2=26–50 cm, 3=51–75 cm, 4=76–100 cm, 5=101–125 cm, and 6=126–150 cm). When shrubs were distributed through multiple height classes, the height of the majority of the shrub cover was recorded in one of the following two height classes, ≤100 cm (≤39.4 in) or >100–150 cm (>39.4–59.0 in).

Tree seedlings: 1993, 1995, 1998, and 2003

All tree seedlings in each 2×2 m (6.5×6.5 ft) vegetation plot were identified to species (except *Carya* sp. in 1998), counted, and recorded by height class. Tree seedling height classes were defined as follows: 1=0–25 cm (0–9.8 in); 2=26–50 cm (10.2–19.7 in); 3=51–75 cm (20.0–29.5 in); 4=76–100 cm (29.9–39.4 in); 5=101–125 cm (39.7–49.2 in); and 6=126–150 cm (49.6–59.0 in).

Statistical Methods

Species richness

We used repeated measures ANOVA to test whether differences in species richness between fenced and unfenced plots occurred over time. We used PROC GLM in SAS 9.1 (SAS Institute, Inc. 2003) with the REPEATED statement to conduct the repeated measures analysis, in which the dependent variable was the difference in number of species between paired fenced and unfenced plots. We considered differences between fenced and unfenced plots (n=30) as subjects with repeated measurements over time modeled using an orthogonal polynomial transformation, in which the spacing of the orthogonal polynomials was the number of years

since 1993 the data were collected (i.e., 0 years for data collected in 1993, 2 for 1995, 5 for 1998, and 10 for 2003). An additional factor in the analysis was site (Mount Joy or Mount Misery). We used MANOVA test criteria and exact F statistics to test hypotheses of time and interaction effects (α=0.05).

Some taxa were classified only to genera (i.e., *Carex*, *Carya*, *Eupatorium*, *Smilax*, *Polygonatum,* and *Vaccinium*) because classification to species did not occur across all years of data collection. Also, using only 2003 data, we calculated the percentage of species that were present in the fenced plots that were also present in the unfenced plots. We summarized these results by plot, by forest stand, and across all plots.

Tree seedling abundance

We used the same repeated measures ANOVA analysis to test whether changes in stem density of all tree seedling species occurred over time, and whether density differed between fenced and unfenced plots.

Principal Components Analysis

We conducted a principal components analysis (PROC PRINCOMP [SAS Institute, Inc. 2003]), in which the analysis used the number of plants (or presence) by plant type (herbaceous, vine, shrub, and tree) on each plot. We used only data from 2003 and analyzed Mount Joy and Mount Misery data separately. We plotted the principal component scores from the first two eigenvectors to illustrate differences between fenced and unfenced plots. These plots provide a means of assessing how fenced and unfenced plots differed according to plant counts (or presence) by plant type.

Stocking rates

Guidelines for acceptable abundance of tree seedlings and small saplings for forest regeneration are 25 seedlings per 12.57 m^2 (135.3 ft^2) (McWilliams et al. 2002), in which weights are applied according to height class (Table 1). The percentage of plots with adequate seedling abundance is referred to as a stocking rate. Any combination of weighted stem counts $\geq$25 seedlings/12.57 m^2 (135.3 ft^2) is considered adequate stocking.

Stem count data collected at Valley Forge National Historical Park included only tree species seedlings up to 150 cm in height and were recorded in slightly different height classes (Table 2). We weighted these height classes as closely as possibly to those defined by McWilliams et al. (2002) and corrected for the different sized sampling areas. Seedlings <5.1 cm (<2 in) in height should not be included in calculating stocking rates because most of these individuals do not survive; therefore, we assigned seedlings in the >0–25 cm (>0–9.8 in) class a weight of zero. Also, we were missing the last two height classes used by McWilliams et al. (2002). Using the revised criteria, we calculated stocking rates for all tree species, only native tree species, and only deer-preferred tree species. Exotic tree species excluded for the analysis of native tree species were Norway maple (*Acer platanoides*), tree of heaven (*Ailanthus altissima*), princess tree (*Paulownia tomentosa*), and sweet cherry (*Prunus avium*) (see Appendix A).

Table 1. Height classes of tree seedlings and small saplings and assigned weights from U.S. Forest Service, Forest Inventory Analysis (McWilliams et al. 2002), used to calculate stocking rates of advanced forest regeneration.

Height class	Weight
5.1–14.7 cm	1
>14.7–30.0 cm	1
>30–90 cm	2
>90–150 cm	20
>150–310 cm	50
>310 cm and <12.5 cm dbh	50

Table 2. Height classes of tree seedlings used at Valley Forge National Historical Park, 1993–2003, and assigned weights for calculating stocking rates of advanced forest regeneration.

Height class	Weight
>0–25 cm	0
>25–50 cm	1
>50–75 cm	2
>75–100 cm	2
>100–125 cm	20
>125–150 cm	20

Indicator species

There are several herbaceous species that have been suggested as indicators of deer browsing intensity (Latham et al. 2005). The species that occur in Valley Forge National Historical Park are Jack-in-the-pulpit (*Arisaema triphyllum*), wild sarsaparilla (*Aralia nudicaulis*), sweet cicely (*Osmorhiza claytoni*), Indian cucumber root (*Medeola virginiana*), *Trillium* spp., white wood aster (*Symphyotrichum divaricatum*), and jewelweed (*Impatiens capensis*). However, we excluded jewelweed because is it strongly associated with riparian habitats and would likely require a different sampling scheme to be adequately represented in samples. We summarized which of these species were present in fenced and unfenced plots.

Results

Species Richness

We did not distinguish between native and exotic species in our analysis of species richness because excluding or including exotic species had no effect on the results. The repeated measures ANOVA indicated that species richness increased over time ($F_{3,26}$=6.27, P=0.002) in fenced plots on both Mount Misery and Mount Joy. In unfenced plots, species richness exhibited no change or a slight decline over time in both areas (Table 3, Figure 2). Species richness was greater on Mount Joy but differences in species richness between fenced and unfenced plots were similar for both areas ($F_{1,28}$=3.19, P=0.085), and differences between areas did not change over time ($F_{3,26}$=1.14, P=0.350). From 1993 to 2003 on Mount Misery, the total number of species increased 32% (from 31 to 41 species) in fenced plots, and decreased 15% (from 27 to 23 species) in unfenced plots (Appendixes B–E). On Mount Joy, the total number of species increased 27% (from 56 to 71 species) in fenced plots and declined 6% (from 51 to 48 species) in unfenced plots.

By 2003, on average over both sites, only 28% of species that were present in the fenced plots (average no. species in fenced plots = 10.4) were present in the unfenced plots (Table 4). The Mount Misery area averaged 34% (average no. species in fenced plots = 8.0), whereas the Mount Joy area averaged 23% (average no. species in fenced plots = 12.8). The average number of species in unfenced plots that were not found in the paired fenced plots on Mount Misery and Mount Joy was 1.5 and 2.9, respectively.

Over all years, the number of fenced and unfenced plots containing exotic species exhibited similar changes observed for overall species richness. In general, exotic species were present in more fenced plots than in unfenced plots, and individual fenced plots contained more exotic species than did individual unfenced plots. Twenty-two of the 24 exotic species recorded from plots have been present in at least one fenced plot during one or more of the four sampling periods (Table 5). Two species were first observed in fenced plots in 1998 and two species were first observed in fenced plots in 2003. The overall increase in the occurrence of exotic species in plots between 1993 and 2003 is due solely to an increase observed on fenced plots on Mount Joy (78 to 95 plots [number of occurrences per plot summed over all the plots]).

Table 3. Average number of species present in fenced and unfenced plots on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

	Mount Misery				Mount Joy			
	Fenced		Unfenced		Fenced		Unfenced	
Year	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
1993	6.7	5.2–8.2	5.1	3.7–6.4	9.4	6.4–12.4	7.2	4.8–9.6
1995	7.4	5.6–9.2	4.9	3.5–6.3	10.9	7.4–14.4	5.9	3.2–8.7
1998	8.3	6.3–10.2	4.4	3.0–5.7	11.4	8.6–14.2	5.2	2.7–7.7
2003	8.0	5.7–10.3	3.9	2.8–5.1	12.8	9.9–15.7	5.9	3.5–8.3

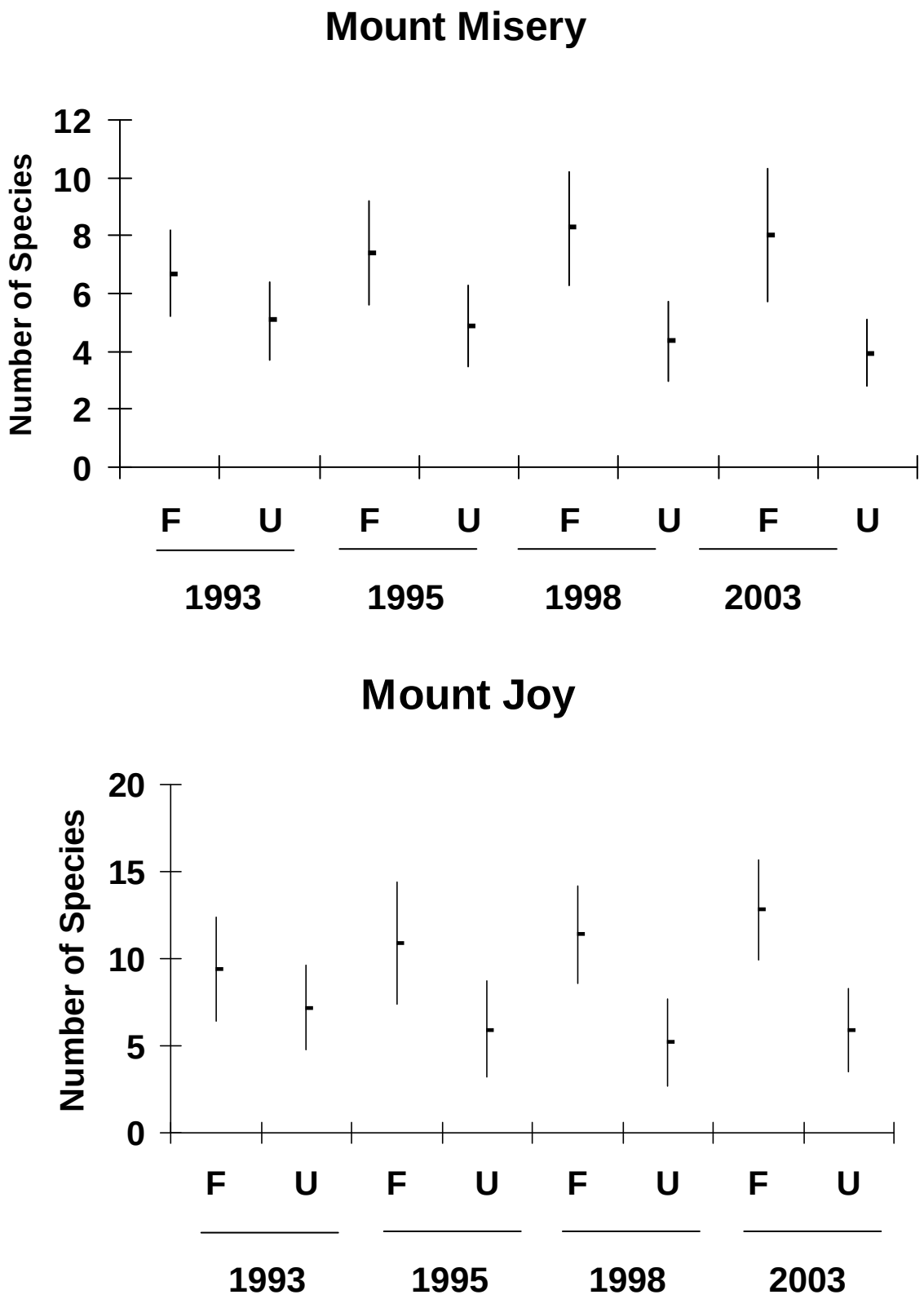

Figure 2. Average number of species found in fenced (F) and unfenced (U) plots on Mount Misery and Mount Joy during 1993, 1995, 1998, and 2003, Valley Forge National Historical Park, Pennsylvania.

Table 4. Number of species present in fenced plots and percentage of these species present in the paired unfenced plots on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 2003.

Area	Site No.	No. of Species Present in Fenced Plot	Percent of Species Present in Fenced Plot also Present in Unfenced Plot
Mount Misery	1	9	33
	2	6	0
	3	3	33
	4	9	33
	5	3	33
	6	15	7
	7	13	31
	8	7	29
	9	13	23
	10	7	29
	11	10	50
	12	3	67
	13	6	33
	14	13	38
	15	3	67
Mount Joy	16	25	44
	17	18	22
	18	6	17
	19	14	36
	20	12	17
	21	16	6
	22	9	22
	23	17	6
	24	12	8
	25	18	17
	26	5	40
	27	8	38
	28	12	50
	29	11	9
	30	9	11

Table 5. Number of fenced and unfenced plots containing exotic species on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

Area and Treatment	Scientific name	Common name	Plant Type	1993	1995	1998	2003
Mount Misery							
fenced	*Polygonum caespitosum*	smartweed	herb	0	0	0	1
fenced	*Prunus avium*	sweet cherry	tree	0	0	1	0
fenced	*Lonicera japonica*	Japanese honeysuckle	vine	1	0	0	0
fenced	*Polygonum aviculare*	knotweed	herb	1	0	1	0
fenced	*Celastrus orbiculatus*	oriental bittersweet	vine	1	1	0	0
fenced	*Microstegium vimineum*	stilt grass	herb	3	0	0	0
Total species occurrences – fenced plots				6	1	2	1
Mount Misery (continued)							
unfenced	*Berberis thunbergii*	Japanese Barberry	shrub	0	0	1	0
unfenced	*Celastrus orbiculatus*	oriental bittersweet	vine	0	0	1	0
unfenced	*Microstegium vimineum*	stilt grass	herb	1	1	0	0
Total species occurrences – unfenced plots				1	1	2	0
Total species occurrences – Mount Misery				7	2	4	1
Mount Joy							
fenced	*Ailanthus altissima*	tree of heaven	tree	0	0	0	2
fenced	*Euonymus alata*	burning bush	shrub	0	0	0	4
fenced	*Lonicera morrowii*	morrow honeysuckle	shrub	0	0	1	3
fenced	*Polygonum aviculare*	knotweed	herb	0	0	3	0
fenced	*Lonicera maackii*	amur honeysuckle	shrub	0	0	3	7
fenced	*Paulownia tomentosa*	princess tree	tree	0	1	0	0
fenced	*Rhodotypos scandens*	jetbead	shrub	0	1	1	1
fenced	*Rosa multiflora*	multiflora rose	shrub	0	1	1	1
fenced	*Acer platanoides*	Norway maple	tree	0	2	1	4
fenced	*Berberis thunbergii*	Japanese barberry	shrub	1	0	0	0
fenced	*Cardamine impatiens*	bitter-cress	herb	1	0	1	1
fenced	*Prunus avium*	sweet cherry	tree	1	0	4	1
fenced	*Ligustrum vulgare*	common privet	shrub	1	1	2	8
fenced	*Duchesnea indica*	indian strawberry	herb	2	0	1	0
fenced	*Alliaria petiolata*	garlic-mustard	herb	2	0	6	7
fenced	*Lonicera japonica*	Japanese honeysuckle	vine	2	7	4	5
fenced	*Rubus phoenicolasius*	wineberry	shrub	3	2	2	6
fenced	*Pastinaca sativa*	wild parsnip	herb	3	3	0	0
fenced	*Celastrus orbiculatus*	oriental bittersweet	vine	5	5	8	7
fenced	*Polygonum caespitosum*	smartweed	herb	6	3	0	2
fenced	*Microstegium vimineum*	stilt grass	herb	6	3	2	5
fenced	*Malva neglecta*	common mallow	herb	6	4	0	0
Total species occurrences – fenced plots				39	33	40	64
unfenced	*Ligustrum vulgare*	common privet	shrub	0	0	0	1
unfenced	*Ranunculus bulbosus*	bulbous buttercup	herb	0	0	0	1
unfenced	*Taraxacum officinale*	common dandelion	herb	0	0	0	1
unfenced	*Euonymus alata*	burning bush	shrub	0	0	0	2
unfenced	*Lonicera maackii*	amur honeysuckle	shrub	0	0	0	3
unfenced	*Acer platanoides*	Norway maple	tree	0	1	0	0
unfenced	*Polygonum aviculare*	knotweed	herb	0	1	4	1
unfenced	*Cardamine impatiens*	bitter-cress	herb	1	1	1	1
unfenced	*Alliaria petiolata*	garlic-mustard	herb	1	1	5	3
unfenced	*Prunus avium*	sweet cherry	tree	2	0	0	0
unfenced	*Duchesnea indica*	Indian strawberry	herb	2	2	2	1
unfenced	*Pastinaca sativa*	wild parsnip	herb	3	2	0	0
unfenced	*Lonicera japonica*	Jap. honeysuckle	vine	3	4	2	2

Table 5. Number of plots containing exotic species in fenced and unfenced plots on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003 (continued).

Area and Treatment	Scientific name	Common name	Plant Type	1993	1995	1998	2003
Mount Joy (cont'd.)							
unfenced	*Microstegium vimineum*	stilt grass	herb	4	6	8	7
unfenced	*Malva neglecta*	common mallow	herb	5	7	0	0
unfenced	*Celastrus orbiculatus*	oriental bittersweet	vine	5	7	5	2
unfenced	*Rubus phoenicolasius*	wineberry	shrub	6	2	2	2
unfenced	*Polygonum caespitosum*	smartweed	herb	7	3	1	4
Total species occurrences – unfenced plots				39	37	30	31
Total species occurrences – Mount Joy				78	70	70	95

The number of plots containing at least one exotic species changed little over time in either site or in fenced and unfenced plots. On Mount Misery, between 1993 and 2003, the number of fenced plots with at least one exotic species declined from five plots to one plot and unfenced plots with at least one exotic species decreased from one plot to zero plots. On Mount Joy, between 1993 and 2003, the number of fenced plots with at least one exotic species increased from ten plots to 12 plots, and the number of unfenced plots containing at least one exotic species decreased from 11 plots to nine plots.

Tree Seedling Abundance

We failed to detect a change in seedling counts between fenced and unfenced plots over time ($F_{3,26}$=2.23, P=0.109) or between Mount Joy and Mount Misery ($F_{3,26}$=0.37, P=0.547), or an interaction between time and areas ($F_{3,26}$=1.14, P=0.351). However, there was some evidence of an increase in seedling counts over time because a univariate test of the hypothesis of no time effect was rejected ($F_{3,84}$=3.67, Huyn-Feldt P=0.041). Both areas had increasing mean counts of seedlings, but the variability was large (Table 6, Figure 3).

By 2003, on Mount Misery there were 7.1 (SE=1.56) more species of tree seedlings, on average, in fenced plots than in unfenced plots. On Mount Joy by 2003, on average, there were 11.3 (SE=1.54) more species in fenced plots than in unfenced plots. Average number of seedlings and standard deviation by species, height class, fencing treatment, and area are presented in Table 7. Pooling seedling counts across species, but not height classes, indicated that in unfenced plots no seedlings were found taller than height class 1 on either Mount Misery or Mount Joy (Table 8).

Table 6. Average number of tree seedlings present in fenced and unfenced plots on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

	Mount Misery				Mount Joy			
	Fenced		Unfenced		Fenced		Unfenced	
Year	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI	$\bar{x}$	95% CI
1993	17.7	8.4–27.0	11.8	3.9–19.7	6.5	2.0–10.9	3.7	1.1–6.2
1995	21.7	8.9–34.4	10.0	2.8–17.2	12.6	4.1–21.1	4.2	-2.1–10.5
1998	24.7	10.4–39.1	8.3	1.6–15.0	10.8	4.1–17.5	3.5	-1.4–8.8
2003	26.0	10.1–41.9	9.3	5.0–13.5	24.1	6.7–41.5	9.7	0.7–18.8

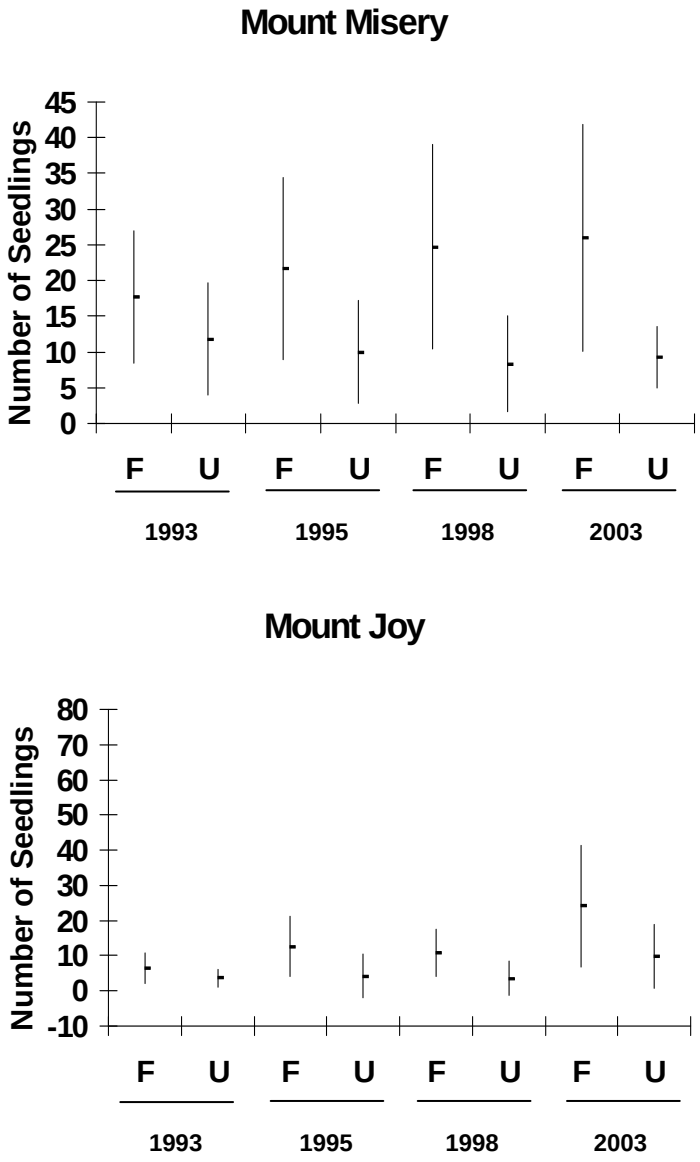

Figure 3. Average number of tree seedlings found on fenced (F) and unfenced (U) plots on Mount Misery and Mount Joy during 1993, 1995, 1998, and 2003, Valley Forge National Historical Park, Pennsylvania.

Table 7. Average number of tree seedlings per plot and standard deviation (SD), by species and height class, for Mount Joy and Mount Misery, Valley Forge National Historical Park, Pennsylvania, 2003.

		Mount Joy				Mount Misery			
	Height	Fenced		Unfenced		Fenced		Unfenced	
Scientific Name	Class	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Acer platanoides	1	0.5	1.25						
	3	0.1	0.26						
	4	0.1	0.26						
Acer rubrum	1	11.9	22.20	3.0	9.01	5.6	8.12	4.3	5.89
	2	0.6	1.24			0.3	0.90		
	3	0.1	0.26			0.1	0.26		
Ailanthus altissima	1	0.8	2.83						
Carya glabra	1	0.1	0.35			0.1	0.26		
Carya spp.	1			0.1	0.52				
Cercis canadensis	1			0.1	0.26				
Fraxinus americana	1	1.3	3.24	2.3	8.51	0.1	0.26		
	2	0.1	0.35						
	3	0.3	0.60						
	4	0.1	0.52						
Fraxinus sp.	1	0.5	1.60	0.9	2.50	0.1	0.26	0.5	1.55
Liriodendron tulipifera	1			0.3	1.05	0.1	0.26	0.2	0.77
	3	0.1	0.26						
	4	0.1	0.26						
Malus spp.	1	0.3	1.05						
	2	0.1	0.26						
Nyssa sylvatica	1	1.6	5.70	1.4	5.15	1.3	1.58	0.5	0.99
	2	0.2	0.56			0.7	1.58		
	3	0.1	0.52			0.6	2.06		
	4	0.1	0.26			0.1	0.35		
	5	0.1	0.26			0.1	0.26		
	6	0.1	0.26			0.1	0.52		
Pinus strobus	1	1.07	1.28	0.1	0.35				
Prunus avium	1	0.2	0.41						
Prunus serotina	1	0.1	0.26			0.4	0.74	1.1	2.87
	2	0.1	0.26						
	3	0.1	0.26			0.1	0.26		
Quercus alba	1					0.2	0.77		
Quercus coccinea	1							0.1	0.26
Quercus montana	1					9.5	22.35	0.1	0.26
	2	0.1	0.26			0.6	1.24		
Quercus rubra	1	0.1	0.26			0.1	0.26	0.1	0.35
	2	0.1	0.26						
Quercus spp.	1			0.1	0.26				
Quercus velutina	1	0.2	0.41			0.6	1.12	0.1	0.26
	2					0.1	0.52		
Sassafras albidum	1	3.1	6.06	1.4	4.10	4.0	3.96	2.4	4.21
	2					0.9	2.33		
	3					0.2	0.41		
	5					0.1	0.26		
Ulmus rubra	2	0.1	0.26						
Unknown	1							0.4	1.30

[a] Height classes: 1 = 0–25 cm, 2 = 26–50 cm, 3 = 51–75 cm, 4 = 76–100 cm, 5 = 101–125 cm, and 6 = 126–150 cm.

Table 8. Average number of tree seedlings per plot and standard deviation (SD), by height class, for Mount Joy and Mount Misery, Valley Forge National Historical Park, Pennsylvania, 2003.

	Mount Joy				Mount Misery			
Height	Fenced		Unfenced		Fenced		Unfenced	
Class	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	21.5	30.59	9.7	16.33	21.9	28.76	9.3	7.70
2	1.4	1.55			2.7	2.85		
3	0.7	0.82			0.9	2.02		
4	0.3	0.62			0.1	0.35		
5	0.1	0.26			0.1	0.35		
6	0.1	0.26			0.1	0.52		

Principal Components Analysis

The first two eigenvectors of the principal components analysis explained 73% of the variation on Mount Misery and 70% of the variation on Mount Joy for the 2003 vegetation data (Table 9). The eigenvectors for Mount Misery indicated positive loadings on all four species types for the first eigenvector, and negative loadings on vines and herbs and positive loadings for trees and shrubs on the second eigenvector (Table 9). For Mount Joy, the first eigenvector loading was negative for trees and positive for all other species types, and the second eigenvector had a negative loading for herbs and positive loadings for the remaining species types (Table 9). Plots of the principal components scores for the first two eigenvectors indicated that fenced plots tended to have a greater number of plant species, as indicated by the greater scores for fenced plots (Figure 4).

Stocking Rates

Percent of plots adequately stocked (based on the criteria in Table 2), using all tree data, is presented in Table 10 for each year sampled. Excluding exotic tree species resulted in one less fenced plot in 1998 to be counted as adequately stocked. Excluding species not preferred by deer reduced 1998 and 2003 percentages by 3–4% for fenced plots (1 less plot classified as adequately stocked in each of the years). The mean number of weighted stem counts per plot increased in fenced plots and declined to zero in unfenced plots from 1993 to 2003 (Table 11).

Indicator Species

In 2003, four of six herbaceous species known to occur in the park that have been proposed as potential indicator species of the effects of deer browsing (Latham et al. 2005) occurred in nine of 30 fenced plots (1–3 species present), and one species (Jack-in-the-pulpit) was present in six of 30 unfenced plots. Whenever Jack-in-the-pulpit was present in an unfenced plot, it also occurred in the paired fenced plot (Table 12).

Table 9. Principal components eigenvectors using stem counts per plot for seedlings of tree species and number of times recorded per plot for shrub, vine, and herb species on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 2003.

	Mount Misery		Mount Joy	
Variable	Principal Component 1	Principal Component 2	Principal Component 1	Principal Component 2
Vines	0.6502	-0.2727	0.4967	0.5970
Herbs	0.6609	-0.2012	0.4893	-0.3975
Trees	0.1498	0.7405	-0.4233	0.6345
Shrubs	0.3435	0.5803	0.5785	0.2879
Proportion of variation explained	0.43	0.30	0.48	0.22

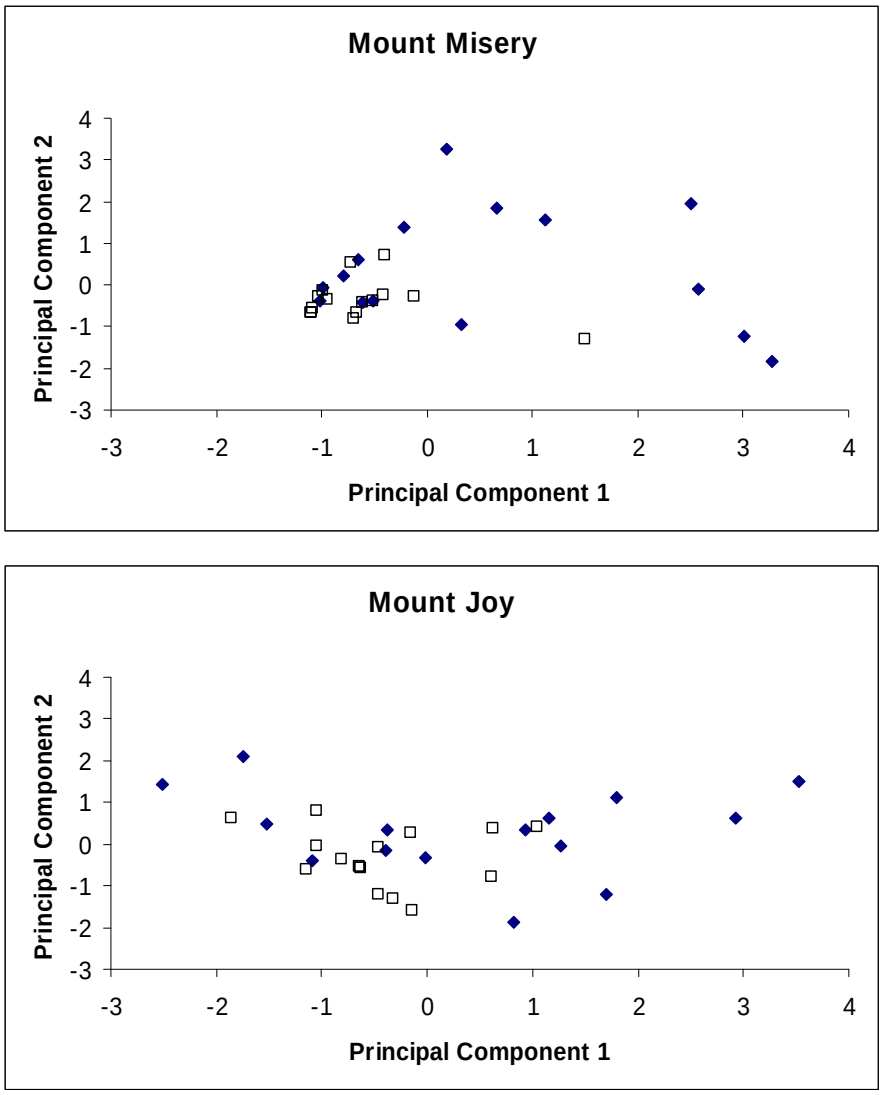

Figure 4. Plots of principal components scores for fenced (solid diamonds) and unfenced (open squares) plots on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 2003, using stem counts per plot for seedlings of tree species and number of times recorded per plot for shrub, vine, and herb species.

Table 10. Percent of fenced and unfenced plots, using all tree data, on both Mount Misery and Mount Joy adequately stocked (n = 30 for each cell), Valley Forge National Historical Park, Pennsylvania, 1993–2003.

Plot Type	1993	1995	1998	2003
Fenced	3	3	13	27
Unfenced	3	0	0	0

Table 11. Mean number of stems (weighted counts) per fenced and unfenced plot on both Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

	1993		1995		1998		2003	
Plot Type	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Fenced	4.8	2.6	4.4	1.2	7.5	2.2	25.2	8.9
Unfenced	1.4	0.9	0.2	0.1	0.1	0.1	0.0	

Table 12. Occurrence (0 = absent; 1 = present) of Jack-in-the-pulpit (*Arisaema triphyllum*), wild sarsaparilla (*Aralia nudicaulis*), sweet cicely (*Osmorhiza claytoni*), Indian cucumber root (*Medeola virginiana*), and *Trillium* spp. in fenced and unfenced plots on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

Area and Site Number	Treatment	*Species*	1993	1995	1998	2003
Mount Misery						
7	Fenced	*Medeola virginiana*	1	1	1	0
7	Unfenced	*Medeola virginiana*	1	0	0	0
8	Fenced	*Aralia nudicaulis*	0	0	1	1
8	Unfenced	*Aralia nudicaulis*	0	0	0	0
9	Fenced	*Aralia nudicaulis*	0	0	1	0
9	Unfenced	*Aralia nudicaulis*	0	0	0	0
10	Fenced	*Medeola virginiana*	0	0	0	0
10	Unfenced	*Medeola virginiana*	1	0	1	0
11	Fenced	*Aralia nudicaulis*	1	0	1	1
11	Unfenced	*Aralia nudicaulis*	0	0	0	0
11	Fenced	*Arisaema triphyllum*	0	0	0	1
11	Unfenced	*Arisaema triphyllum*	0	0	0	1
11	Fenced	*Medeola virginiana*	0	1	1	1
11	Unfenced	*Medeola virginiana*	1	1	1	0
11	Fenced	*Trillium* spp.	0	1	0	0
11	Unfenced	*Trillium* spp.	1	0	0	0
Mount Joy						
16	Fenced	*Arisaema triphyllum*	0	1	1	1
16	Unfenced	*Arisaema triphyllum*	0	1	0	1
17	Fenced	*Arisaema triphyllum*	0	0	1	1
17	Unfenced	*Arisaema triphyllum*	0	0	1	1
17	Fenced	*Osmorhiza claytoni*	0	0	1	1
17	Unfenced	*Osmorhiza claytoni*	0	0	0	0
17	Fenced	*Trillium* spp.	1	0	0	0
17	Unfenced	*Trillium* spp.	1	0	0	0
19	Fenced	*Arisaema triphyllum*	0	0	0	1
19	Unfenced	*Arisaema triphyllum*	0	0	1	1
19	Fenced	*Osmorhiza claytoni*	0	0	1	0
19	Unfenced	*Osmorhiza claytoni*	0	0	0	0
21	Fenced	*Aralia nudicaulis*	0	0	1	0
21	Unfenced	*Aralia nudicaulis*	0	0	0	0
21	Fenced	*Osmorhiza claytoni*	1	1	0	0
21	Unfenced	*Osmorhiza claytoni*	0	0	0	0
24	Fenced	*Arisaema triphyllum*	0	0	0	1
24	Unfenced	*Arisaema triphyllum*	0	0	0	0
25	Fenced	*Arisaema triphyllum*	0	1	0	1
25	Unfenced	*Arisaema triphyllum*	0	1	0	1
25	Fenced	*Osmorhiza claytoni*	1	1	0	0
25	Unfenced	*Osmorhiza claytoni*	0	0	0	0
25	Fenced	*Trillium* spp.	1	0	0	0
25	Unfenced	*Trillium* spp.	0	0	0	0
27	Fenced	*Medeola virginiana*	0	0	0	0
27	Unfenced	*Medeola virginiana*	0	1	0	0
28	Fenced	*Arisaema triphyllum*	0	1	0	1
28	Unfenced	*Arisaema triphyllum*	0	1	1	1
28	Fenced	*Osmorhiza claytoni*	0	0	0	0
28	Unfenced	*Osmorhiza claytoni*	0	1	0	0
29	Fenced	*Arisaema triphyllum*	0	1	0	1
29	Unfenced	*Arisaema triphyllum*	0	1	0	0

Conclusions

The statistical analysis of species richness indicates substantial changes between 1993 and 2003, during which richness generally increased over time in fenced plots and and exhibited no change or a slight decline in unfenced plots. Species richness in fenced plots and in unfenced plots was greater on Mount Joy than on Mount Misery in each year sampled. The occurrence of specific species in fenced and unfenced plots over time, and in the two forest stands, can be studied in Appendixes B–E. Mean stem density of tree seedlings in fenced plots increased over time, but because of high variability among plots we failed to detect a statistically significant change. In 2003, unfenced plots generally contained about one-third the number of tree seedlings present in fenced plots.

Advanced regeneration stocking rates are a measure developed by foresters (McWilliams et al. 2002) to assess the potential for forests to regenerate following timber harvest. By applying this metric to fenced and unfenced plots, it indicates that the percentage of fenced plots which have sufficient advanced regeneration has increased (from 3% to 27% of plots; Table 5) during 1993–2003; whereas since 1995 no unfenced plots have had adequate advanced regeneration. Table 7 provides a means to examine species-specific changes. Finally, neither fenced nor unfenced plots generally contained a large number of exotic species (Table 5).

The principal components analysis and resulting plots of the first two eigenvectors (Figure 4) are another way to visualize the differences between fenced and unfenced plots. Most unfenced plots are clustered together because they are similar in number of species by plant type (herbaceous, vine, tree, or shrub), whereas the fenced plots have been released from deer browsing and differences among plots are expressed by a greater scatter of points in Figure 4. However, fenced plots still exhibit substantial overlap with unfenced plots.

A number of herbaceous species have been identified as potential indicator species regarding the effects of deer browsing (Latham et al. 2005). The indicator species that occur in Valley Forge National Historical Park (Jack-in-the-pulpit, wild sarsaparilla, sweet cicely, Indian cucumber root, *Trillium* spp., and white wood aster) are relatively rare. In 2003, four of these species were found in only nine of 30 paired sites, of which six sites contained just one species (Jack-in-the-pulpit) in the unfenced plot. More plots, perhaps each plot larger in size, or a longer monitoring time will likely be needed to detect changes with these indicator species.

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Appendix A. Tree species observed in vegetation plots, and their deer preference, on Mount Misery and Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

Species	Deer Preference[a]	Notes
tree of heaven	0	Exotic
Norway maple	1	Exotic, assumed to be preferred like all native *Acer*
princess tree	0	Exotic
red maple	1	
silver maple	1	
sugar maple	1	
black birch	1	
hornbeam	0	Unknown preference
pignut hickory	0	
American chestnut	1	Unknown preference
hackberry	0	
redbud	0	Unknown preference
flowering dogwood	1	
American beech	0	
white ash	1	
yellow poplar	1	Highly preferred
crabapple	1	
black gum	1	Highly preferred
hop hornbeam	0	
white pine	0	
sweet cherry	0	
black cherry	0	
white oak	1	
scarlet oak	1	Highly preferred
chestnut oak	1	Highly preferred
northern red oak	1	Highly preferred
black oak	1	Highly preferred
sassafrass	1	
American elm	0	
slippery (red) elm	0	

[a] 0 - Species ranked as having low or unknown preference by deer.
1 - Species ranked as having moderate or high preference by deer.

Rankings from Latham et al. (2005).

Appendix B. The year species were observed during sampling of unfenced plots on Mount Misery, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Arisaema triphyllum	Jack-in-the-pulpit	Herb	No	No				X
Chimaphila maculata	striped wintergreen	Herb	No	No				X
Dennstaedtia punctilobula	hay scented fern	Herb	No	No				X
Fraxinus sp.	ash	Tree	No	No				X
Monotropa uniflora	Indian-pipe	Herb	No	No				X
Quercus coccinea	scarlet oak	Tree	No	No				X
Quercus velutina	black oak	Tree	No	No				X
Amelanchier sp.	juneberry	Herb	No	No			X	
Berberis thunbergii	Japanese barberry	Shrub	Yes	Yes			X	
Carya ovata	shagbark hickory	Tree	No	No			X	
Celastrus orbiculatus	oriental bittersweet	Vine	Yes	Yes			X	
Cornus florida	flowering dogwood	Tree	No	No			X	
Pteridium aquilinum	bracken fern	Herb	No	No			X	
Rhododendron periclymenoides	pink azalea	Shrub	No	No			X	
Rubus occidentalis	black raspberry	Herb	No	No			X	
Carex digitalis	sedge	Herb	No	No			X	X
Gaylussacia baccata	black huckleberry	Shrub	No	No			X	X
Maianthemum canadense	wild lily of the valley	Herb	No	No			X	X
Betula lenta	black birch	Tree	No	No		X		
Castanea dentata	American chestnut	Tree	No	No		X		
Ostrya virginiana	hop hornbeam	Tree	No	No		X		
Prunus serotina	wild black cherry	Tree	No	No		X	X	X
Thelypteris noveboracensis	New York fern	Herb	No	No		X	X	X
Carpinus caroliniana	hornbeam	Tree	No	No	X			
Maianthemum racemosum	false Solomon's seal	Herb	No	No	X			
Panax quinquefolius	ginseng	Herb	No	No	X			
Polygonatum sp.	Solomon's seal	Herb	No	No	X			
Symplocarpus foetidus	skunk cabbage	Herb	No	No	X			
Trillium sp.	trillium	Herb	No	No	X			
Toxicodendron radicans	poison ivy	Vine	No	No	X		X	

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Fagus grandifolia	American beech	Tree	No	No	X	X		
Microstegium vimineum	stilt grass	Herb	Yes	Yes	X	X		
Phlox sp.	phlox	Herb	No	No	X	X		
Quercus alba	white oak	Tree	No	No	X	X		
Smilax rotundifolia	greenbrier	Vine	No	No	X	X		
Kalmia latifolia	mountain laurel	Shrub	No	No	X	X		X
Quercus rubra	northern red oak	Tree	No	No	X	X		X
Athyrium filix-femina	northern lady fern	Herb	No	No	X	X	X	
Chimaphila umbellata	pipsissewa	Herb	No	No	X	X	X	
Medeola virginiana	Indian cucumber root	Herb	No	No	X	X	X	
Viburnum acerifolium	maple-leaf viburnum	Shrub	No	No	X	X	X	
Acer rubrum	red maple	Tree	No	No	X	X	X	X
Hamamelis virginiana	witch hazel	Shrub	No	No	X	X	X	X
Liriodendron tulipifera	tuliptree	Tree	No	No	X	X	X	X
Nyssa sylvatica	blackgum	Tree	No	No	X	X	X	X
Parthenocissus quinquefolia	Virginia creeper	Vine	No	No	X	X	X	X
Quercus montana	chestnut oak	Tree	No	No	X	X	X	X
Sassafras albidum	sassafras	Tree	No	No	X	X	X	X
Vaccinium corymbosum	highbush blueberry	Shrub	No	No	X	X	X	X

[a] Rhoads, A. F., and W. M. Klein, Jr. 1993. The Vascular Flora of Pennsylvania: Annotated Checklist and Atlas. American Philosophical Society. Philadelphia, PA.

[b] Invasive: Pennsuylvania Department of Conservation and Natural Resources. 2005. Invasive Exotic Plant Managment Tutorial for Natural Lands Managers. Mid-Atlantic Exotic Pest Plant Council, Inc. Lisa Smith, Principal Investigator. http://www.dcnr.state.pa.us/forestry/invasivetutorial/List.htm.

Appendix C. The year species were observed during sampling of fenced plots on Mount Misery, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Arisaema triphyllum	Jack-in-the-pulpit	Herb	No	No				X
Chimaphila maculata	striped wintergreen	Herb	No	No				X
Fraxinus americana	white ash	Tree	No	No				X
Fraxinus sp.	ash	Tree	No	No				X
Gaylussacia frondosa	blue huckleberry	Shrub	No	No				X
Gaylussacia sp.	huckleberry species	Shrub	No	No				X
Isotria verticillata	whorled pogonia	Herb	No	No				X
Polygonum caespitosum	smartweed	Herb	Yes	No				X
Pteridium aquilinum	bracken fern	Herb	No	No				X
Quercus velutina	black oak	Tree	No	No				X
Rubus pensilvanicus	Pennsylvania blackberry	Herb	No	No				X
Carpinus caroliniana	hornbeam	Tree	No	No			X	
Lysimachia quadrifolia	whorled loosestrife	Herb	No	No			X	
Prenanthes altissima	rattlesnake root	Herb	No	No			X	
Prunus avium	sweet cherry	Tree	Yes	No			X	
Rubus pubescens	dwarf raspberry	Herb	No	No			X	
Toxicodendron radicans	poison ivy	Vine	No	No			X	
Dennstaedtia punctilobula	hay scented fern	Herb	No	No			X	X
Desmodium nudiflorum	naked tick-trefoil	Herb	No	No			X	X
Gaylussacia baccata	black huckleberry	Shrub	No	No			X	X
Kalmia angustifolia	sheep laurel	Herb	No	No			X	X
Polygonatum biflorum	smooth Solomon's seal	Herb	No	No			X	X
Prunus serotina	wild black cherry	Tree	No	No			X	X
Rhododendron periclymenoides	pink azalea	Shrub	No	No			X	X
Viburnum dentatum	arrowwood vibernum	Shrub	No	No			X	X
Boehmeria cylindrica	false nettle	Herb	No	No		X		
Lactuca canadensis	wild lettuce	Herb	No	No		X		
Rubus recurvicaulis	dewberry	Herb	No	No		X		

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Trillium sp.	trillium	Herb	No	No		X		
Viola sp.	violet	Herb	No	No		X		
Acer saccharinum	silver maple	Tree	No	No		X	X	
Carya glabra	pignut hickory	Tree	No	No		X	X	X
Thelypteris noveboracensis	New York fern	Herb	No	No		X	X	X
Uvularia perfoliata	bellwort	Herb	No	No		X	X	X
Vitis aestivalis	summer grape	Vine	No	No		X	X	X
Lonicera japonica	Japanese honeysuckle	Vine	Yes	Yes	X			
Microstegium vimineum	stilt grass	Herb	Yes	Yes	X			
Pilea pumila	clearweed	Herb	No	No	X			
Polygonum aviculare	knotweed	Herb	Yes	No	X		X	
Aralia nudicaulis	wild sarsparilla	Herb	No	No	X		X	X
Amphicarpa bracteata	hog peanut	Herb	No	No	X	X		
Celastrus orbiculatus	Oriental bittersweet	Vine	Yes	Yes	X	X		
Fagus grandifolia	American beech	Tree	No	No	X	X		
Panax quinquefolius	ginseng	Herb	No	No	X	X		
Phlox sp.	phlox	Herb	No	No	X	X		
Athyrium filix-femina	northern lady fern	Herb	No	No	X	X	X	
Chimaphila umbellata	pipsissewa	Herb	No	No	X	X	X	
Cornus florida	flowering dogwood	Tree	No	No	X	X	X	
Acer rubrum	red maple	Tree	No	No	X	X	X	X
Carex communis	sedge	Herb	No	No	X	X	X	X
Hamamelis virginiana	witch hazel	Shrub	No	No	X	X	X	X
Kalmia latifolia	mountain laurel	Shrub	No	No	X	X	X	X
Liriodendron tulipifera	tuliptree	Tree	No	No	X	X	X	X
Maianthemum racemosum	false Solomon's seal	Herb	No	No	X	X	X	X
Medeola virginiana	Indian cucumber root	Herb	No	No	X	X	X	X
Nyssa sylvatica	blackgum	Tree	No	No	X	X	X	X
Parthenocissus quinquefolia	Virginia creeper	Vine	No	No	X	X	X	X
Quercus alba	white oak	Tree	No	No	X	X	X	X
Quercus montana	chestnut oak	Tree	No	No	X	X	X	X

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Quercus rubra	northern red oak	Tree	No	No	X	X	X	X
Sassafras albidum	sassafras	Tree	No	No	X	X	X	X
Smilax glauca	greenbrier	Vine	No	No	X	X	X	X
Symphyotrichum divaricatum	white wood aster	Herb	No	No	X	X	X	X
Vaccinium angustifolium	lowbush blueberry	Shrub	No	No	X	X	X	X
Viburnum acerifolium	maple-leaf viburnum	Shrub	No	No	X	X	X	X

[a] Rhoads, A. F., and W. M. Klein, Jr. 1993. The Vascular Flora of Pennsylvania: Annotated Checklist and Atlas. American Philosophical Society. Philadelphia, PA.

[b] Invasive: Pennsuylvania Department of Conservation and Natural Resources. 2005. Invasive Exotic Plant Managment Tutorial for Natural Lands Managers. Mid-Atlantic Exotic Pest Plant Council, Inc. Lisa Smith, Principal Investigator. http://www.dcnr.state.pa.us/forestry/invasivetutorial/List.htm.

Appendix D. The year species were observed during sampling of unfenced plots on Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Euonymus alata	burning bush	Shrub	Yes	Yes				X
Fraxinus sp.	ash	Tree	No	No				X
Ligustrum vulgare	common privet	Shrub	Yes	Yes				X
Lonicera maackii	amur honeysuckle	Shrub	Yes	Yes				X
Quercus sp.	oak species	Tree	No	No				X
Ranunculus bulbosus	bulbous buttercup	Herb	Yes	No				X
Rubus pensilvanicus	Pennsylvania blackberry	Herb	No	No				X
Taraxacum officinale	common dandelion	Herb	Yes	No				X
Vitis sp.	grape	Vine	No	No				X
Ageratina altissima	white snakeroot	Herb	No	No			X	
Cornus florida	flowering dogwood	Tree	No	No			X	
Sanicula marilandica	black snake root	Herb	No	No			X	
Cercis canadensis	redbud	Tree	No	No			X	X
Fraxinus americana	white ash	Tree	No	No			X	X
Pinus strobus	white pine	Tree	No	No			X	X
Viburnum prunifolium	black haw	Shrub	No	No			X	X
Vitis aestivalis	summer grape	Vine	No	No			X	X
Vitis vulpina	frost grape	Vine	No	No			X	X
Acer platanoides	norway maple	Tree	Yes	Yes		X		
Leersia virginica	white grass	Herb	No	No		X		
Medeola virginiana	Indian cucumber root	Herb	No	No		X		
Osmorhiza claytoni	sweet cicely	Herb	No	No		X		
Ulmus rubra	slippery elm	Tree	No	No		X		
Arisaema triphyllum	Jack-in-the-pulpit	Herb	No	No		X	X	X
Polygonum aviculare	knotweed	Herb	Yes	No		X	X	X
Viola sp.	violet	Herb	No	No		X	X	X
Lycopus sp.	water-horehound	Herb	No	No	X			
Maianthemum racemosum	false Solomon's seal	Herb	No	No	X			
Prunus avium	sweet cherry	Tree	Yes	No	X			
Ranunculus recurvatus	hooked crowfoot	Herb	No	No	X			
Rubus hispidus	swamp dewberry	Herb	No	No	X			

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Trillium sp.	trillium	Herb	No	No	X			
Uvularia perfoliata	bellwort	Herb	No	No	X			
Carya sp.	hickory	Tree	No	No	X			X
Polygonatum sp.	Solomon's seal	Herb	No	No	X			X
Smilax sp.	greenbriar	Vine	No	No	X			X
Viburnum acerifolium	maple-leaf viburnum	Shrub	No	No	X			X
Prunus serotina	wild black cherry	Tree	No	No	X		X	
Circaea alpina	enchanter's nightshade	Herb	No	No	X		X	X
Liriodendron tulipifera	tuliptree	Tree	No	No	X		X	X
Toxicodendron radicans	poison ivy	Vine	No	No	X		X	X
Fagus grandifolia	American beech	Tree	No	No	X	X		
Fragaria virginiana	wild strawberry	Herb	No	No	X	X		
Galium circaezans	wild licorice	Herb	No	No	X	X		
Malva neglecta	common mallow	Herb	Yes	No	X	X		
Pastinaca sativa	wild parsnip	Herb	Yes	No	X	X		
Phlox sp.	phlox	Herb	No	No	X	X		
Polygonum virginianum	jumpseed	Herb	No	No	X	X		
Prunus virginiana	choke cherry	Tree	No	No	X	X		
Quercus montana	chestnut oak	Tree	No	No	X	X		
Quercus rubra	northern red oak	Tree	No	No	X	X		
Symphyotrichum divaricatum	white wood aster	Herb	No	No	X	X		
Carex pensylvanica	sedge	Herb	No	No	X	X		X
Carex sp.	sedge	Herb	No	No	X	X		X
Carex swanii	sedge	Herb	No	No	X	X		X
Betula lenta	black birch	Tree	No	No	X	X	X	
Acer rubrum	red maple	Tree	No	No	X	X	X	X
Alliaria petiolata	garlic-mustard	Herb	Yes	Yes	X	X	X	X
Cardamine impatiens	bitter-cress	Herb	Yes	No	X	X	X	X
Celastrus orbiculatus	Oriental bittersweet	Vine	Yes	Yes	X	X	X	X
Duchesnea indica	Indian strawberry	Herb	Yes	No	X	X	X	X
Lindera benzoin	spicebush	Shrub	No	No	X	X	X	X
Lonicera japonica	Japanese honeysuckle	Vine	Yes	Yes	X	X	X	X
Microstegium vimineum	stilt grass	Herb	Yes	Yes	X	X	X	X
Nyssa sylvatica	blackgum	Tree	No	No	X	X	X	X

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Oxalis stricta	common yellow wood-sorrel	Herb	No	No	X	X	X	X
Parthenocissus quinquefolia	Virginia creeper	Herb	No	No	X	X	X	X
Pilea pumila	clearweed	Herb	No	No	X	X	X	X
Polygonum caespitosum	smartweed	Herb	Yes	No	X	X	X	X
Rubus phoenicolasius	wineberry	Herb	Yes	Yes	X	X	X	X
Sassafras albidum	sassafras	Tree	No	No	X	X	X	X
Vaccinium pallidum	blueberry	Shrub	No	No	X	X	X	X
Vaccinium sp.	blueberry	Shrub	No	No	X	X	X	X
Vaccinium stamineum	deerberry	Shrub	No	No	X	X	X	X

[a] Rhoads, A. F., and W. M. Klein, Jr. 1993. The Vascular Flora of Pennsylvania: Annotated Checklist and Atlas. American Philosophical Society. Philadelphia, PA.

[b] Invasive: Pennsuylvania Department of Conservation and Natural Resources. 2005. Invasive Exotic Plant Managment Tutorial for Natural Lands Managers. Mid-Atlantic Exotic Pest Plant Council, Inc. Lisa Smith, Principal Investigator. http://www.dcnr.state.pa.us/forestry/invasivetutorial/List.htm.

Appendix E: The year species were observed during sampling of fenced plots on Mount Joy, Valley Forge National Historical Park, Pennsylvania, 1993–2003.

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Ageratina altissima	white snakeroot	Herb	No	No				X
Ailanthus altissima	tree of heaven	Tree	Yes	Yes				X
Chimaphila maculata	striped wintergreen	Herb	No	No				X
Desmodium nudiflorum	naked tick-trefoil	Herb	No	No				X
Dryopteris carthusiana	spinulose woodfern	Herb	No	No				X
Dryopteris marginalis	marginal woodfern	Herb	No	No				X
Euonymus alata	burning bush	Shrub	Yes	Yes				X
Fraxinus sp.	ash	Tree	No	No				X
Geum canadense	white avens	Herb	No	No				X
Malus sp.	crabapple	Tree	No	No				X
Monotropa uniflora	Indian-pipe	Herb	No	No				X
Phytolacca americana	pokeweed	Herb	No	No				X
Quercus velutina	black oak	Tree	No	No				X
Sanicula sp.	sanicle	Herb	No	No				X
Smilax sp.	greenbriar	Vine	No	No				X
Vitis sp.	grape	Vine	No	No				X
Acer saccharum	sugar maple	Tree	No	No			X	
Aralia nudicaulis	wild sarsaparilla	Herb	No	No			X	
Chimaphila umbellata	pipsissewa	Herb	No	No			X	
Lysimachia quadrifolia	whorled loosestrife	Herb	No	No			X	
Phryma leptostachya	lopseed	Herb	No	No			X	
Polygonum aviculare	knotweed	Herb	Yes	No			X	
Rubus pubescens	dwarf raspberry	Herb	No	No			X	
Ulmus americana	American elm	Tree	No	No			X	
Uvularia sessilifolia	wild oats	Herb	No	No			X	
Cimicifuga racemosa	black cohosh	Herb	No	No			X	X
Eupatorium sp.	joe pye weed	Herb	No	No			X	X
Eupatorium purpureum	sweetscented joe pye weed	Herb	No	No			X	X
Lonicera maackii	amur honeysuckle	Shrub	Yes	Yes			X	X
Lonicera morrowii	morrow honeysuckle	Shrub	Yes	Yes			X	X
Prunus serotina	wild black cherry	Tree	No	No			X	X
Pteridium aquilinum	bracken fern	Herb	No	No			X	X

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998	2003
Rhododendron periclymenoides	pink azalea	Shrub	No	No			X	X
Rubus pensilvanicus	Pennsylvania blackberry	Herb	No	No			X	X
Vitis vulpina	frost grape	Vine	No	No			X	X
Acer saccharinum	silver maple	Tree	No	No		X		
Celtis occidentalis	hackberry	Tree	No	No		X		
Fragaria virginiana	wild strawberry	Herb	No	No		X		
Hamamelis virginiana	witch hazel	Shrub	No	No		X		
Ostrya virginiana	hop hornbeam	Tree	No	No		X		
Paulownia tomentosa	princess tree	Tree	Yes	Yes		X		
Prenanthes altissima	rattlesnake root	Herb	No	No		X		
Prunus virginiana	choke cherry	Tree	No	No		X		
Rubus hispidus	swamp dewberry	Herb	No	No		X		
Rubus occidentalis	black raspberry	Herb	No	No		X		
Rubus recurvicaulis	dewberry	Herb	No	No		X		
Lactuca canadensis	wild lettuce	Herb	No	No		X		X
Ulmus rubra	slippery elm	Tree	No	No		X		X
Geum virginianum	cream-colored avens	Herb	No	No		X	X	
Quercus alba	white oak	Tree	No	No		X	X	
Acer platanoides	Norway maple	Tree	Yes	Yes		X	X	X
Arisaema triphyllum	Jack-in-the-pulpit	Herb	No	No		X	X	X
Fraxinus americana	white ash	Tree	No	No		X	X	X
Galium circaezans	wild licorice	Herb	No	No		X	X	X
Podophyllum peltatum	may-apple	Herb	No	No		X	X	X
Quercus rubra	northern red oak	Tree	No	No		X	X	X
Rhodotypos scandens	jetbead	Herb	Yes	No		X	X	X
Rosa multiflora	multiflora rose	Shrub	Yes	Yes		X	X	X
Berberis thunbergii	Japanese barberry	Shrub	Yes	No	X			
Hackelia virginiana	beggar's lice	Herb	No	No	X			
Lobelia inflata	Indian tobacco	Herb	No	No	X			
Trillium sp.	trillium	Herb	No	No	X			
Viburnum dentatum	arrowwood vibernum	Shrub	No	No	X			
Symphyotrichum divaricatum	white wood aster	Herb	No	No	X			X
Cryptotaenia canadensis	honewart	Herb	No	No	X		X	
Duchesnea indica	Indian strawberry	Herb	Yes	No	X		X	
Galium triflorum	sweet-scented bedstraw	Herb	No	No	X		X	

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998		2003
Alliaria petiolata	garlic-mustard	Herb	Yes	Yes	X		X		X
Cardamine impatiens	bitter-cress	Herb	Yes	No	X		X		X
Liriodendron tulipifera	tuliptree	Tree	No	No	X		X		X
Prunus avium	sweet cherry	Tree	Yes	No	X		X		X
Fagus grandifolia	American beech	Tree	No	No	X	X			
Malva neglecta	common mallow	Herb	Yes	No	X	X			
Pastinaca sativa	wild parsnip	Herb	Yes	No	X	X			
Phlox sp.	phlox	Herb	No	No	X	X			
Vitis aestivalis	summer grape	Vine	No	No	X	X			
Geranium carolinianum	wild geranium	Herb	No	No	X	X			X
Oxalis stricta	common yellow wood-sorrel	Herb	No	No	X	X			X
Polygonum caespitosum	smartweed	Herb	Yes	No	X	X			X
Amphicarpa bracteata	hog peanut	Herb	No	No	X	X	X		
Athyrium filix-femina	northern lady fern	Herb	No	No	X	X	X		
Betula lenta	black birch	Tree	No	No	X	X	X		
Cercis canadensis	redbud	Tree	No	No	X	X	X		
Cornus florida	flowering dogwood	Tree	No	No	X	X	X		
Pilea pumila	clearweed	Herb	No	No	X	X	X		
Sanicula marilandica	black snake root	Herb	No	No	X	X	X		
Acer rubrum	red maple	Tree	No	No	X	X	X		X
Carex gracilescens	sedge	Herb	No	No	X	X	X		X
Carya sp.	hickory	Tree	No	No	X	X	X		X
Celastrus orbiculatus	Oriental bittersweet	Vine	Yes	Yes	X	X	X		X
Circaea alpina	enchanter's nightshade	Herb	No	No		X	X	X	X
Hepatica nobilis	liverleaf	Herb	No	No		X	X	X	X
Kalmia latifolia	mountain laurel	Shrub	No	No		X	X	X	X
Ligustrum vulgare	common privet	Shrub	Yes	Yes		X	X	X	X
Lindera benzoin	spicebush	Shrub	No	No		X	X	X	X
Lonicera japonica	Japanese honeysuckle	Vine	Yes	Yes		X	X	X	X
Maianthemum racemosum	false Solomon's seal	Herb	No	No		X	X	X	X
Microstegium vimineum	stilt grass	Herb	Yes	Yes		X	X	X	X
Nyssa sylvatica	blackgum	Tree	No	No		X	X	X	X
Osmorhiza claytoni	sweet cicely	Herb	No	No		X	X	X	X
Parthenocissus quinquefolia	Virginia creeper	Vine	No	No		X	X	X	X
Polygonatum sp.	Solomon's seal	Herb	No	No		X	X	X	X

Scientific name	Common name	Plant type	Exotic[a]	Invasive[b]	1993	1995	1998		2003
Polygonum virginianum	jumpseed	Herb	No	No		X	X	X	X
Quercus montana	chestnut oak	Tree	No	No		X	X	X	X
Rubus phoenicolasius	wineberry	Herb	Yes	Yes		X	X	X	X
Sanguinaria canadensis	bloodroot	Herb	No	No		X	X	X	X
Sassafras albidum	sassafras	Tree	No	No		X	X	X	X
Toxicodendron radicans	poison ivy	Vine	No	No		X	X	X	X
Uvularia perfoliata	bellwort	Herb	No	No		X	X	X	X
Vaccinium sp. / *Gaylussacia* sp.	blueberry	Shrub	No	No		X	X	X	X
Viburnum acerifolium	maple-leaf viburnum	Shrub	No	No		X	X	X	X
Viburnum prunifolium	black haw	Shrub	No	No		X	X	X	X
Viola sp.	violet	Herb	No	No		X	X	X	X

[a] Rhoads, A. F., and W. M. Klein, Jr. 1993. The Vascular Flora of Pennsylvania: Annotated Checklist and Atlas. American Philosophical Society. Philadelphia, PA.

[b] Invasive: Pennsuylvania Department of Conservation and Natural Resources. 2005. Invasive Exotic Plant Managment Tutorial for Natural Lands Managers. Mid-Atlantic Exotic Pest Plant Council, Inc. Lisa Smith, Principal Investigator. http://www.dcnr.state.pa.us/forestry/invasivetutorial/List.htm.

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS D-107 April 2008

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U.S. Department of the Interior

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