

**LONG-TERM VEGETATION MONITORING OF
FORESTED ECOSYSTEMS AT
HOPEWELL FURNACE NATIONAL HISTORIC SITE
AND VALLEY FORGE NATIONAL HISTORICAL PARK**

T. W. Bowersox and D. S. Larrick

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Professor of Silviculture and Research Assistant

School of Forest Resources
The Pennsylvania State University
University Park, PA 16802

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SUMMARY

Representative forest communities at Hopewell Furnace National Historic Site and Valley Forge National Historical Park were inventoried to determine the requirements for establishing a comprehensive long-term monitoring plan for each location. The expected long-term monitoring program would provide a quantitative estimate of major temporal changes that may be occurring in the density and species composition in the overstory and understory plants. Our estimates were based on inventories from five forest communities at Hopewell Furnace National Historic Site and eight forest communities at Valley Forge National Historical Park. Overall, the tree-dominated communities at Hopewell Furnace National Historic Site and Valley Forge National Historical Park were similar in species present and number of stems by size classes. Differences were limited to Valley Forge National Historical Park having greater numbers of sapling-size shrub species, and sapling- and tree-size tree species. Valley Forge National Historical Park also had greater numbers of seedling-size shrub and tree stems per hectare. Hopewell Furnace National Historic Site had greater numbers of sapling- and tree-sized shrub and tree stems per hectare.

We believe that an inventory can be developed to provide Hopewell Furnace National Historic Site and Valley Forge National Historical Park with an adequate database for establishing a comprehensive long-term monitoring program. At Hopewell Furnace National Historic Site, 70 sample points with 1 - 0.04 hectare plot for the sapling-sized and tree-sized parameters and 2 - 2.0 m² plots for the seedling-sized and herbaceous plant parameters are recommended. At Valley Forge National Historical Park, we recommend 101 sample points with 1 - 0.04 hectare plot for the sapling-sized and tree-sized parameters and 1 - 2.0 m² plot for the seedling-sized and herbaceous plant parameters.

INTRODUCTION

Hopewell Furnace National Historic Site was established in 1938 to preserve an example of the 1700-1800's cold-blast charcoal fired iron furnace industry. Park management strategies are designed to preserve and interpret the site to represent an ironmaking community in late eighteenth and nineteenth centuries. Eastern deciduous forest occupies 257 ha of the total 345 ha at the site. Hopewell Furnace National Historic Site park management objectives are to manage the natural resources to support the cultural values of the site. The forested areas are closely linked to the cultural resources of Hopewell Furnace National Historic Site in that they were repeatedly harvested to supply wood to make the charcoal to fuel the furnaces. The present forest communities are mainly maturing secondary succession communities having a mixture of deciduous species. Russell (1987) identified 12 forest cover types growing in the park. The park is concerned that intrusive alien plants and foraging by an increasing white-tailed deer population have the potential to alter the density and composition of the native herbaceous, shrub and tree vegetation. Russell (1987) and Storm et al. (1994) have conducted vegetation inventories within the park. Vanderwerff (1994) has provided a catalog of the vascular plants of the park. These inventories have provided the park with a forest cover map, vascular plant list, detailed description of two forest stands and an evaluation of deer browsing in two forest stands. Status of an inventory and monitoring program to establish baseline data was rated as being below the NPS-75 standards (Hopewell Furnace National Historic Site 1992). Two long term monitoring programs have been started. One is to detect long-term vegetation changes, and the other is to identify the impacts of white-tailed deer on the park understory (Storm et al. 1994).

Valley Forge National Historical Park was established in 1976 to commemorate the 1777-78 winter encampment of the Continental Army. Park management strategies are designed to help the visitor experience a setting reminiscent of the encampment era. All forested communities in the park are permitted to develop under natural forces and without direct management intervention. There is a concern that aggressive alien plants and white-tailed deer are influencing the density and composition of native herbaceous, shrub and tree components of the park woodlots. There is concern that both of these are changing the forest communities to the extent that the visitor experience will be affected. Status of an inventory and monitoring program to establish baseline data was rated as being below the NPS-75 standards (Valley Forge National Historical Park 1993)

Hopewell Furnace National Historic Site and Valley Forge National Historical Park desire to establish a baseline of species composition and density of the herbaceous, shrub and tree plants in the forest communities, and to conduct long-term monitoring to quantify any potential changes. The purpose of this study was to evaluate representative forest communities at Hopewell Furnace National Historic Site and Valley Forge National Historical Park, and determine the requirements for establishing a comprehensive long-term monitoring plan for each location.

PROCEDURES

We met with Hopewell Furnace National Historic Site personnel and discussed the long-term vegetation monitoring needs for baseline data. We reviewed reports by Russell (1987), Storm et al. (1994) and Vanderwerff (1994) and the Statement for Management for Hopewell Furnace National Historic Site (Cook 1993). Plots established by Russell (1987) were not permanently marked, and we did not find any evidence of these plots when we were conducting our inventories. The 60 plots established by Storm et al. (1994) were permanently located, well-marked and easily located in 1995. A vegetation type map provided by the park was used as a basis for selecting the communities to sample for our study. Communities selected to be sampled were mixed oak - black birch, tulip poplar - oak, tulip poplar - red maple, chestnut oak - scarlet oak - black oak (mixed oak) and red maple (Figure 1). The black walnut and elm communities were not selected because of their small area. The approximate positions of the numbered randomly located sample plots are indicated in Figure 1. The number of plots per community was proportional to size.

We also met with Valley Forge National Historical Park personnel and discussed the long-term vegetation monitoring needs for baseline data. We reviewed reports by Cypher et al. 1985a, Cypher et al. 1985b, various dated and undated plant surveys and a draft copy of the Resources Management Plan (Valley Forge National Historical Park 1993). Forest communities have not been mapped in Valley Forge National Historical Park, and there was no basis for selecting communities to sample. As an alternative, we used the public use map and information provided by park personnel as a basis for selecting the areas to sample. These areas were Washington Chapel, River - Railroad, Railroad - River, Post Office, Basin 21, Wayne's Woods, Mount Misery and Mount Joy (Figure 2). Trees dominated each of the sampling areas except for Basin 21. There were interspersions of herbaceous and tree dominated areas at Basin 21, and only the tree dominated spots were sampled. The approximate positions of the numbered randomly located sample plots are indicated in Figure 2. The number of plots per area was proportional to size.

There are numerous procedures or protocols for inventorying ecosystems but the those of Russell (1996), Storm and Ross (1992), Storm et al. (1994) and, most recently Mahon et al. (1998) would be most applicable for Hopewell Furnace National Historic Site and Valley Forge National Historical Park. There is general agreement that 0.04 ha would be appropriate for inventorying sapling- and tree-sized plants. There is less agreement on plot size for inventorying seedling-sized stems and herbaceous plants, and plots from 2 to 200m² are frequently used. We selected 2 m² plots to provide estimates at the upper range of variation. It is our experience that circular 2 m² (radius 0.80 m) and 4 m² (radius 1.13) plots provide very similar accuracy and precision.

The Storm and Ross (1992) and Storm et al. (1994) protocols were used as a basis for our sampling procedures to establish the requirements for confidently monitoring the forested ecosystems at the two National Park Service units. Herbaceous plants and seedling-, sapling- and tree-sized shrub and tree species were inventoried at each 0.04 ha sample plot. There were 45 - 0.04 ha sample plots at Hopewell Furnace National Historic Site and 49 - 0.04 ha sample plots at Valley Forge National Historical Park. Number of plots per community or area are presented in Tables 1 and 2, and were proportional to size within each National Park Service unit. Definitions and common and scientific names for the species in each plant group are listed

VEGETATION TYPE MAP

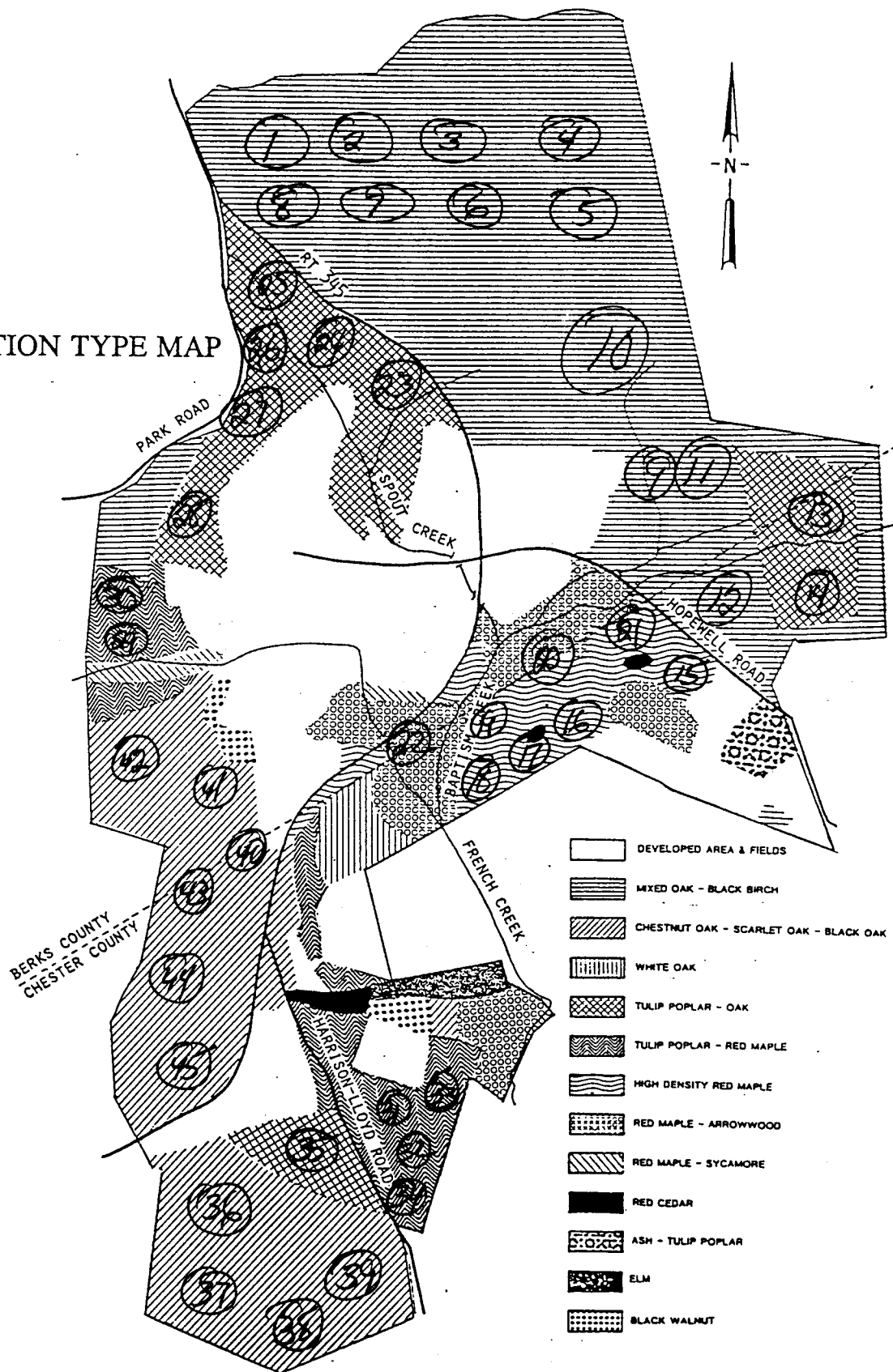


Figure 1. Vegetation type map for Hopewell Furnace National Historic Site with approximate locations of the 45 - 0.04 hectare sample plots.

Table 1. Number of 0.04 hectare sample plots and number^a of shrub, tree and total species for stems that were >150 cm in height and ≥1 cm in diameter at 1.3 m above ground by community at Hopewell Furnace National Historic Site.

Community	Sample Plots (No.)	Shrub (-----Number of Species-----)	Species Tree	Total
Mixed oak - black birch	12	11	14	25
Tulip poplar - oak	9	11	14	25
Tulip poplar - red maple	6	3	9	12
Mixed oak	10	9	15	24
Red maple	8	10	15	25
Overall	45	16	21	37

^a Occurred at least once in the specific community or at least once on all plots for overall.

Table 2. Number of 0.04 hectare sample plots and number^a of shrub, tree and total species for stems >150 cm in height and ≥1 cm in diameter at 1.3 m above ground by community at Valley Forge National Historical Park.

Community	Sample Plots (No.)	Shrub (-----Number of Species-----)	Species Tree	Total
Washington Chapel	6	8	16	24
River - Railroad	4	6	6	12
Railroad - River	4	8	10	18
Post Office	6	3	15	18
Basin 21	6	6	13	19
Wayne's Woods	6	9	7	16
Mount Misery	9	7	11	18
Mount Joy	8	8	17	25
Overall	49	18	32	50

^a Occurred at least once in the specific community or at least once on all plots for overall.

in the Appendices I and II. The number and coverage (%) of broadleaf, grass and vine species were recorded on one 2.0 m² plot per sample point. The number of species and density of seedling-sized stems (stems ≤150 cm in height) of shrub and tree species was recorded as being in either 1-to-50 or 51-to-150 cm height class on one 2.0 m² plot per sample point. The density of sapling-sized and tree-sized shrub and tree species stems (>150 cm height) were recorded by species and diameter at 1.3 m above ground on a 0.04 hectare unit. The stems were assigned to one of 15 - 5 cm diameter classes between 1 and >70 cm. Sapling-size was for those stems in either the 1-to-5 cm or 6-to-10 cm diameter class. Tree-sized stems were those in the >10 cm classes. All data were collected in August 1995.

Average, standard deviation, standard error and confidence interval at the 80, 90 and 95% levels were determined according to the procedures described by Freese (1962). Determinations of the sampling intensities were made from the equation (Freese 1962):

$$N = t^2 S_y^2 / E^2$$

Where:

N = number of sample plots needed

t = student t value at desired level of confidence

S_y = population variance

E = allowable error for desired confidence

The design of the project was to develop a sampling procedure, in particular sampling intensities, for a comprehensive unit wide long-term monitoring program. We also provided estimates for sampling intensities for selected areas or communities. These estimates provide some insight as to what would be required for community specific monitoring.

RESULTS

Hopewell Furnace National Historic Site

Sapling-sized and Tree-sized Stems

For stems that were >150 cm in height, a total of 16 shrub species and 21 tree species was inventoried on the 45 - 0.04 ha sample plots (Tables 1 and 3). The greatest number of shrub species occurred in the mixed oak-black birch and in the tulip poplar-oak communities, both containing 11 species (Table 1). Tree species were greatest in the mixed oak and red maple communities, each with 15 species. The greatest number of total species was 25, occurring in the mixed oak-black birch, tulip poplar-oak, and red maple communities. The tulip poplar-red maple community had the lowest numbers of shrub, tree and total species (3, 9 and 12 species, respectively).

The communities inventoried at this historic site had the greatest density of shrub and tree species stems in the smaller diameter classes. For shrub species (Table 4), the overall average density of sapling-sized (<10 cm in diameter) was 352/ha (97% of stems), and the overall average density of tree-sized stems (>10 cm in diameter) was 11/ha (3% of stems). For the mixed oak-black birch, tulip poplar-oak, tulip poplar-red maple, mixed oak and red maple communities, 96, 99, 100, 92 and 97%, respectively, of shrub species stems were <10 cm in

Table 3. List of shrub and tree species for stems >150 cm in height and ≥ 1 cm in diameter at 1.3 m above ground that were recorded on at least one of the 45 - 0.04 hectare sample plots at Hopewell Furnace National Historic Site.

<u>Shrub Species</u>	<u>Tree Species</u>
American chestnut	American beech
Arrowwood	American elm
Blueberry	Ash spp.
Flowering dogwood	Bigtooth aspen
Hawthorn	Black birch
Ironwood	Black cherry
Mapleleaf viburnum	Blackgum
Mountain laurel	Black oak
Serviceberry	Chestnut oak
Smooth blackhaw	Mazzard cherry
Rhododendron	Mockernut hickory
Sassafras	Northern red oak
Spicebush	Norway maple
Tatarian honeysuckle	Pignut hickory
An Unknown	Red maple
Witch-hazel	Scarlet oak
	Shagbark hickory
	Slippery elm
	White oak
	Yellow birch
	Yellow-poplar

diameter, with the majority of stems (83, 92, 100, 69 and 84%, respectively) in the 1 - 5 cm diameter class. For tree species (Table 4), the overall average density of sapling-sized stems was 448/ha (51% of stems), and the overall average density of tree-sized stems was 424/ha (49% of stems). For the mixed oak-black birch, tulip-poplar-oak, tulip poplar-red maple, mixed oak, and red maple communities, 69, 49, 19, 40 and 48%, respectively, of tree species stems were <10 cm in diameter. The greatest average amount of tree species stems occurred in the 1 - 5 cm diameter class for the mixed oak-black birch, tulip poplar-oak and red maple communities (50, 28, and 39% of stems, respectively). For the tulip poplar-red maple community, the greatest average amount of stems (16%) was in the 11 - 15 cm diameter class. The greatest average amount of stems (32%) was in the 6 - 10 cm diameter class for the mixed oak community. The overall average total density of sapling-sized shrub and tree species combined stems was 815/ha (65% of stems), and the overall total average density of tree-sized stems was 434/ha (35% of stems) (Table 4). The mixed oak-black birch, tulip poplar-oak, tulip poplar-red maple, mixed oak, and red maple communities had 71, 72, 43, 50 and 70%, respectively, of total stems <10 cm in diameter. The greatest average total amount of combined shrub and tree species stems occurred in the 1 - 5 cm diameter class for the mixed oak-black birch, tulip poplar-oak, tulip-poplar-red maple and red maple communities (53, 57, 33 and 59% of stems, respectively). Within the mixed oak community, the greatest average total amount of combined shrub and tree species stems (30%) occurred in the 6 - 10 cm diameter class.

Table 4. Average^a density of stems >150 cm in height by diameter class and community for shrub, tree and total species groups at Hopewell Furnace National Historic Site.

Species Group Community	Diameter Class (cm)														
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	>70
Shrub	(-----Stems per Hectare-----)														
Mixed oak -black birch	115	17	2		2	2									
Tulip poplar -oak	539	42	3												
Tulip poplar -red maple	267														
Mixed oak	130	43	15												
Red maple	625	91	25												
Overall	314	38	9		1	1									
Tree															
Mixed oak -black birch	635	246	148	56	35	33	27	27	10	23	17	2	13	2	8
Tulip poplar -oak	192	147	64	39	53	25	56	25	28	28	19	6		3	6
Tulip poplar -red maple	21	96	100	71	75	42	75	71	63				4		
Mixed oak	68	258	115	103	85	78	40	25	15	5	8	3	3		
Red maple	325	88	94	84	100	66	34	25	22	6	9	3			6
Overall	283	165	108	70	67	48	43	32	18	14	12	3	4	1	4

Table 4. Continued.

Species Group Community	Diameter Class (cm)														
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	>70
Total ^b	(-----Stems per Hectare-----)														
Mixed oak -black birch	750	263	150	56	37	35	27	27	10	23	17	2	13	2	8
Tulip poplar -oak	731	189	67	39	53	25	56	25	28	28	19	6		3	6
Tulip poplar -red maple	288	96	100	71	75	42	75	71	63				4		
Mixed oak	198	301	130	103	85	78	40	25	15	5	8	3	3		
Red maple	950	179	119	84	100	66	34	25	22	6	9	3			6
Overall	597	218	117	70	67	49	43	32	18	14	12	3	4	1	4

^a Based on the number of plots for each community, and all plots for overall.

^b Average density of stems by species groups within community may not add up to total due to rounding.

The overall number of sapling-sized shrub species was 16 (Table 5). *Viburnum* and spicebush were the most abundant species, with overall averages of 92 and 91 stems/ha, respectively. Within the individual communities, the most abundant species were dogwood (29 stems/ha) and *viburnum* (25 stems/ha) in the mixed oak-black birch community, *viburnum* (289 stems/ha) and mountain laurel (108 stems/ha) in the tulip poplar-oak community, spicebush (196 stems/ha) and *viburnum* (63 stems/ha) in the tulip poplar-red maple community, mountain laurel (60 stems/ha) and sassafras (40 stems/ha) in the mixed oak community, and spicebush (234 stems/ha) and other shrubs, including American chestnut, blueberry, hawthorn, great rhododendron and unknown species, (197 stems/ha) in the red maple community. The overall number of sapling-sized tree species was 18 (Table 6). Birch (112 stems/ha) and maple (82 stems/ha) were the most abundant species over the five communities. The dominant species within communities were birch (371 stems/ha) and yellow poplar (292 stems/ha) in the mixed oak-black birch community, blackgum (136 stems/ha) and maple (58 stems/ha) in the tulip poplar-oak community, maple (71 stems/ha) and ash and other trees, including American beech, American elm, and slippery elm, (both 13 stems/ha) in the tulip poplar-red maple community, blackgum (145 stems/ha) and maple (125 stems/ha) in the mixed oak community, and cherry (228 stems/ha) and other trees (91 stems/ha) in the red maple community.

The overall number of tree-sized shrub species was 4 (Table 7). The most abundant species were sassafras and ironwood, with overall averages of 5 and 4 stems/ha, respectively. The most abundant species for the individual communities were sassafras in the tulip poplar-oak and mixed oak communities (3 and 15 stems/ha, respectively), sassafras (4 stems/ha) and dogwood (2 stems/ha) in the mixed oak-black birch community, and ironwood (22 stems/ha) and spicebush (3 stems/ha) in the red maple community. There were no tree-sized shrubs in the tulip poplar-red maple community. The overall number of tree-sized tree species was 19 (Table 8). Across all communities, the most abundant species were maple and oak (both 114 stems/ha). Within communities, the dominant species were birch (117 stems/ha) and oak (94 stems/ha) in the mixed oak-black birch community, birch (86 stems/ha) and oak (81 stems/ha) in the tulip poplar-oak community, yellow poplar (379 stems/ha) and maple (75 stems/ha) in the tulip poplar-red maple community, oak (310 stems/ha) and maple (70 stems/ha) in the mixed oak community, and red maple (319 stems/ha) and ash (34 stems/ha) in the red maple community.

Summary data of sapling-sized and tree-sized shrub and tree species and stems are provided in Tables 9 and 10.

Seedling-sized Stems

For stems <150 cm in height (seedling-sized stems), 15 shrub species and 15 tree species were recorded on at least one of the 45 - 2.0 m² sample plots (Table 11). The greatest number of shrub species (10 species) occurred in the mixed oak community (Table 12). The mixed oak-black birch community had the greatest numbers of tree and total species (11 and 19 species, respectively). The tulip poplar-red maple and red maple communities had the lowest number of shrub species (both 5 species), and the tulip poplar-red maple community had the lowest numbers of tree and total species (5 and 10 species, respectively).

The overall average density of seedling-sized shrub stems was 49,000/ha, with 94% of stems in the 1 - 50 cm height class (Table 13). The mixed oak-black birch, tulip poplar-oak, tulip poplar-red maple, mixed oak, and red maple communities had 100, 97, 94, 89 and 97%, respectively, of

Table 5. Number of 0.04 hectare sample plots^a, number of shrub species^b and average^a density of shrub species stems that were >150 cm in height and ≤10 cm in diameter at 1.3 m above ground, by species group^c and community at Hopewell Furnace National Historic Site.

Community	Sample Plots	Species	Service- berry	Iron- wood	Dog- wood	Witch- hazel	Mountain laurel	Spice- bush	Sassa- fras	Vibru- num	Other Shrubs	Non- native	Total ^d
	(--Number--)		(-----Stems per Hectare-----)										
Mixed oak -black birch	12	11	10	13	29	4	2	13	21	25	2	13	132
Tulip poplar -oak	9	11	3	39	44	108	0	83	3	289	11	0	581
Tulip poplar -red maple	6	3	0	0	8	0	0	196	0	63	0	0	267
Mixed oak	10	9	8	3	13	48	18	13	40	13	5	0	160
Red maple	8	10	6	169	16	0	0	234	3	91	197	0	716
Overall	45	16	6	42	23	36	4	91	10	92	38	3	350

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall.

^c Viburnum included arrowwood, mapleleaf viburnum and smooth blackhaw; Other Shrubs included American chestnut, blueberry, hawthorn, rhododendron and an unknown; Non-native was Tatarian honeysuckle.

^d Average density of stems by species groups within community may not add up to total due to rounding.

Table 6. Number of 0.04 hectare sample plots^a, tree species^b and average^a density of tree species stems that were >150 cm in height and ≤10 cm in diameter at 1.3 m above ground, by species group^c and community at Hopewell Furnace National Historic Site.

Community	Sample Plots	Species	Maple	Birch	Hickory	Ash	Yellow- poplar	Black- gum	Cherry	Oak	Other Tree	Total ^d
	(-Number-)		(-----Stems per Hectare-----)									
Mixed oak -black birch	12	9	108	371	6	0	292	56	6	4	38	881
Tulip poplar -oak	9	10	58	56	3	11	3	136	17	6	50	339
Tulip poplar -red maple	6	6	71	8	0	13	8	0	4	0	13	117
Mixed oak	10	10	125	3	30	0	0	145	8	13	3	328
Red maple	8	13	22	3	16	22	3	22	228	6	91	413
Overall	45	18	82	112	12	8	80	78	48	6	36	449

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall

^c Maple included Norway and red; Birch included black and yellow; Hickory included mockernut, pignut and shagbark; Ash included green and white; Cherry included black and mazzard; Oak included black, chestnut, northern red and white; Other Tree included American beech, American elm and slippery elm.

^d Average density of stems by species groups within community may not add up to total due to rounding.

Table 7. Number of 0.04 hectare sample plots^a, shrub species^b and average^a density of shrub species stems that were >10 cm in diameter at 1.3 m above ground, by species and community at Hopewell Furnace National Historic Site.

Community	Sample Plots	Species	Iron- wood	Dog- wood	Spice- bush	Sassa- fras	Total ^c
	(--Number--)		(-----Stems per Hectare-----)				
Mixed oak - black birch	12	2	0	2	0	4	6
Tulip poplar - oak	9	1	0	0	0	3	3
Tulip poplar - red maple	6	0	0	0	0	0	0
Mixed oak	10	1	0	0	0	15	15
Red maple	8	2	22	0	3	0	25
Overall	45	4	4	1	1	5	10

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall.

^c Average density of stems by species groups within community may not add up to total due to rounding.

Table 8. Number of 0.04 hectare sample plots^a, tree species^b and average^a density of tree species stems that were >150 cm in height and >10 cm in diameter at 1.3 m above ground, by species group^c and community at Hopewell Furnace National Historic Site.

Community	Sample Plots	Species	Maple	Birch	Hickory	Ash	Yellow- poplar	Black- gum	Cherry	Oak	Other Tree	Total ^d
	(--Number--)		(-----Stems per Hectare-----)									
Mixed oak -black birch	12	13	69	117	10	0	50	33	0	94	29	402
Tulip poplar -oak	9	12	72	86	6	3	36	50	0	81	14	350
Tulip poplar -red maple	6	6	75	0	0	13	379	13	21	0	0	500
Mixed oak	10	12	70	5	18	0	5	48	0	310	23	478
Red maple	8	11	319	0	31	34	3	25	6	22	9	450
Overall	45	19	114	49	13	8	73	36	4	114	17	430

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall.

^c Maple included Norway and red; Birch included black and yellow; Hickory included mockernut, pignut and shagbark; Ash included green and white; Cherry included black and mazzard; Oak included black, chestnut, northern red and white; Other Tree included American beech, American elm and bigtooth aspen.

^d Average density of stems by species groups within community may not add up to total due to rounding.

Table 9. Number of 0.04 hectare sample plots, number of shrub and tree species^a and average^b density of shrub and tree species stems that were >150 cm in height and ≤10 cm in diameter at 1.3 m above ground, by community at Hopewell Furnace National Historic Site.

Community	Sample	Species		Stems		
	Plots	Shrubs	Trees	Shrub	Tree	Total ^c
	(-----Number-----)			(Number per Hectare)		
Mixed oak - black birch	12	11	9	132	881	1013
Tulip poplar - oak	9	11	10	581	339	920
Tulip poplar - red maple	6	3	6	267	117	384
Mixed oak	10	9	10	160	328	488
Red maple	8	10	13	716	413	1128
Overall	45	16	18	350	464	814

^a Based on the number of plots for each community, and total number of plots for overall. Shrubs included American chestnut, arrowwood, blueberry, flowering dogwood, hawthorn, ironwood, mapleleaf viburnum, mountain laurel, serviceberry, smooth blackhaw, rhododendron, sassafras, spicebush, Tatarian honeysuckle, an unknown and witch-hazel. Tree species included American beech, American elm, ash spp., black birch, black cherry, blackgum, black oak, chestnut oak, mazzard cherry, mockernut hickory, northern red oak, pignut hickory, red maple, shagbark hickory, slippery elm, white oak, yellow birch and yellow-poplar.

^b Based on the number of plots for each community and all plots for overall.

^c Density of shrub and tree stems may not equal total due to rounding.

Table 10. Number of 0.04 hectare sample plots, number of shrub and tree species^a and average^b density of shrub and tree species stems that were >10 cm in diameter by community at Hopewell Furnace National Historic Site.

Community	Sample	Species		Stems		
	Plots	Shrubs	Trees	Shrub	Tree	Total ^c
	(-----Number-----)			(Number per Hectare)		
Mixed oak - black birch	12	2	13	6	402	408
Tulip poplar - oak	9	1	12	3	350	353
Tulip poplar - red maple	6	0	6	0	501	501
Mixed oak	10	1	12	15	478	493
Red maple	8	2	11	25	450	475
Overall	45	4	19	11	430	440

^a Based on the number of plots for each community, and total number of plots for overall. Shrubs included flowering dogwood, ironwood, sassafras and spicebush. Tree species included American beech, American elm, ash spp., bigtooth aspen, black birch, black cherry, blackgum, black oak, chestnut oak, mazzard cherry, mockernut hickory, northern red oak, Norway maple, pignut hickory, red maple, shagbark hickory, white oak, yellow birch and yellow-poplar.

^b Based on the number of plots for each community and all plots for overall.

^c Density of shrub and tree stems may not equal total due to rounding.

Table 11. List of shrub and tree species for stems ≤ 150 cm in height that were recorded on at least one of the 45 - 2.0 m² sample plots at Hopewell Furnace National Historic Site.

Shrub Species	Tree Species
Arrowwood	American beech
Blackberry-raspberry	American elm
Blueberry	Ash spp.
Greenbriar spp.	Black birch
Ironwood	Black cherry
Japanese barberry	Blackgum
Mapleleaf viburnum	Black oak
Rhododendron	Chestnut oak
Rose spp.	Mazzard cherry
Sassafras	Mockernut hickory
Serviceberry	Northern red oak
Smooth blackhaw	Pignut hickory
Spicebush	Red maple
Tatarian honeysuckle	White oak
Witch-hazel	Yellow-poplar

Table 12. Number of 2.0 m² sample plots and number of shrub, tree and total species^a for stems that were ≤ 150 cm in height by community at Hopewell Furnace National Historic Site.

Community	Sample Plots (No.)	Shrub (-----Number of Species-----)	Species Tree	Total
Mixed oak - black birch	12	8	11	19
Tulip poplar - oak	9	9	8	17
Tulip poplar - red maple	6	5	5	10
Mixed oak	10	10	7	17
Red maple	8	5	7	12
Overall	45	15	15	30

^a Occurred at least once in the specific community or at least once on all plots for overall.

Table 13. Number of 2.0 m² sample plots and average density^a of seedling-sized (stems ≤150 cm in height) shrub, tree and total species^b stems (x 1000) by height class and community at Hopewell Furnace National Historic Site.

Community	Sample Plots (No.)	Shrubs		Trees		Total ^c	
		Height Class		Height Class		Height Class	
		1-50	51-150	1-50	51-150	1-50	51-150
(-----1000 Stems per Hectare-----)							
Mixed oak - black birch	12	33	0	36	<1	69	<1
Tulip poplar - oak	9	62	2	24	0	86	2
Tulip poplar - red maple	6	33	2	13	0	46	2
Mixed oak	10	66	8	24	2	90	9
Red maple	8	30	1	22	0	52	1
Overall	45	46	3	25	<1	71	3

^a Based on the number of plots for each community and all plots for overall.

^b Shrubs included arrowwood, blackberry, blueberry, greenbriar spp., ironwood, Japanese barberry, mapleleaf viburnum, rhododendron, rose spp., sassafras, serviceberry, smooth blackhaw, spicebush, Tatarian honeysuckle and witch-hazel. Tree species included American beech, American elm, ash spp., black birch, black cherry, blackgum, black oak, chestnut oak, mazzard cherry, mockernut hickory, northern red oak, pignut hickory, red maple, white oak and yellow-poplar.

^c Density of shrub and tree stems may not equal total due to rounding.

shrub stems in the 1 - 50 cm height class. For seedling-sized trees, the overall average density of stems was about 26,000/ha, with about 96% of stems in the 1 - 50 cm height class (Table 13). Approximately 97, 100, 100, 92 and 100% of tree stems occurred in the 1 - 50 cm height class for the mixed oak-black birch, tulip poplar-oak, tulip poplar-red maple, mixed oak and red maple communities, respectively. For total seedling-sized shrubs and trees (Table 13), the overall average density of stems was 74,000/ha, with 96% occurring in the 1 - 50 cm height class. The mixed oak-black birch, tulip poplar-oak, tulip poplar-red maple, mixed oak and red maple communities had 99, 98, 96, 91 and 98%, respectively, of stems in the 1 - 50 cm height class.

Of the seedling-sized shrub species (Table 14), other shrubs, including blackberry and raspberry, blueberry, rhododendron and greenbriar, and spicebush were most abundant (overall averages of 30,000 and 7,000 stems/ha, respectively). Within communities, the dominant species were other shrubs (24,000 stems/ha) and viburnum (8,000 stems/ha) in the mixed oak-black birch community, other shrubs (35,000 stems/ha) and serviceberry (14,000 stems/ha) in the tulip

Table 14. Number of 2.0 m² sample plots^a, shrub species^b and average^a density of shrub seedling-sized (stems ≤150 cm in height) stems (x 1000), by species group^c and community at Hopewell Furnace National Historic Site.

Community	Sample Plots	Species	Service- berry	Iron- wood	Witch- hazel	Spice bush	Sassa- fras	Vibru- num	Other Shrubs	Non- native	Total ^d
	(--Number--)		(-----1000 Stems per Hectare-----)								
Mixed oak -black birch	12	8	0	0	0	1	1	8	24	0	34
Tulip poplar -oak	9	9	14	0	1	3	0	11	35	1	64
Tulip poplar -red maple	6	5	0	0	0	31	1	1	3	1	36
Mixed oak	10	10	1	1	1	0	5	1	64	3	74
Red maple	8	5	0	1	0	11	0	4	14	0	31
Overall	45	15	3	<1	<1	7	1	5	30	1	48

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall.

^c Viburnum included arrowwood, mapleleaf viburnum and smooth blackhaw; Other Shrubs included blackberry-raspberry, blueberry, greenbriar and rhododendron; Non-native included Japanese barberry, Tatarian honeysuckle and rose spp.

^d Average density of stems by species groups within community may not add up to total due to rounding.

poplar-oak community, spicebush (31,000 stems/ha) and other shrubs (3,000 stems/ha) in the tulip poplar-red maple community, other shrubs (64,000 stems/ha) and sassafras (5,000 stems/ha) in the mixed oak community, and other shrubs (14,000 stems/ha) and spicebush (11,000 stems/ha) in the red maple community. Of the seedling-sized tree species, red maple (9,000 stems/ha) and oak (7,000 stems/ha) were most abundant (Table 15). For the individual communities, the most abundant species were red maple (16,000 stems/ha) and oak (8,000 stems/ha) in the mixed oak-black birch community, red maple (9,000 stems/ha) and yellow poplar (7,000 stems/ha) in the tulip poplar-oak community, yellow poplar (5,000 stems/ha) and ash and cherry (both 3,000 stems/ha) in the tulip poplar-red maple community, oak (17,000 stems/ha) and red maple (6,000 stems/ha) in the mixed oak community, and cherry (11,000 stems/ha) and red maple (5,000 stems/ha) in the red maple community.

Summary data of seedling-sized shrub and tree species and stems are provided in Table 16.

Herbaceous

Totals of 18 broadleaf, 2 grass, and 6 vine species were inventoried on the 45 - 2.0 m² sample plots (Table 17). The tulip poplar-red maple community (Table 18) had the greatest numbers of broadleaf, vine, and total species (13, 6 and 20 species, respectively). Grass species were greatest in the tulip poplar-oak and red maple communities, both with 2 species. The mixed oak community had the lowest numbers of broadleaf (4), grass (0) and total (7) species. Vine species were lowest (2) in the mixed oak-black birch community.

The overall average percent coverage of broadleaves, grasses, vines and total was 12, 18, 2 and 32%, respectively (Table 19). Broadleaf and vine coverage was greatest in the tulip poplar-red maple community (35 and 6% coverage, respectively). Grass (68%) and total (85%) coverage was greatest in the red maple community. The mixed oak-black birch community had the lowest broadleaf and total coverage (1 and 5%, respectively). Grass (0%) and vine (<1%) coverage was lowest in the mixed oak community.

Inventory Requirements

Selected statistics and number of sample plots needed for number of shrub, tree and total species per plot; and density of shrub, tree and total stems; and the sampling intensity needed to achieve 80, 90 and 95% probability by species group were calculated for tree-, sapling- and seedling-sized components. Values for tree-, sapling- and seedling-sized components are presented in Tables 20, 21 and 22, respectively. Selected statistics for number of herbaceous species and herbaceous coverage per 2.0 m² plot by herbaceous group, and sampling intensity needed to achieve 80, 90 and 95% probability by herbaceous group are presented in Table 23 and Table 24, respectively.

The 0.04 hectare plot was considered to be the primary basis for selecting the number of plots needed to precisely determine the population means for the desired parameters of the forested communities. From Tables 20 and 21, it appears that 70 - 0.04 hectare plots should produce acceptable results in inventorying the number of shrub, tree and total species, as well as the density of shrub, tree and total species stems for the sapling- and tree-sized stems. An inventory from 70 plots would be expected to have 80 to 90% level of confidence in estimating all parameters, except the number of shrub species and shrub species stems per hectare that were

Table 15. Number of 2.0 m² sample plots^a and tree species^b and average^a density of tree seedling-sized (stems ≤150 cm in height) stems (x 1000), by species group^c and community at Hopewell Furnace National Historic Site.

Community	Sample Plots	Species	Red Maple	Black Birch	Hickory	Ash	Yellow- poplar	Black- gum	Cherry	Oak	Other Tree	Total ^d Tree
	(-Number-)		(-----1000 Stems per Hectare-----)									
Mixed oak -black birch	12	11	16	<1	3	0	0	4	3	8	<1	36
Tulip poplar -oak	9	8	9	1	1	0	7	2	1	3	0	24
Tulip poplar -red maple	6	5	2	0	0	3	5	0	3	0	0	13
Mixed oak	10	7	6	0	1	0	0	1	1	17	0	26
Red maple	8	7	5	0	0	2	2	0	11	1	1	22
Overall	45	15	9	<1	1	1	3	1	3	7	<1	26

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall

^c Hickory included mockernut and pignut; Ash included green and white; Cherry included black and mazzard; Oak included black, chestnut, northern red and white; Other Tree included American beech and American elm.

^d Average density of stems by species groups within community may not add up to total due to rounding.

Table 16. Number of 2.0 m² sample plots, number of shrub and tree species^a and average^b density of shrub, tree and total species seedling-sized (stems ≤150 cm in height) stems (x 1000) by community at Hopewell Furnace National Historic Site.

Community	Sample	Species		Stems		
	Plots	Shrubs	Trees	Shrub	Tree	Total ^c
	(-----Number-----)			(---1000 /Hectare--)		
Mixed oak - black birch	12	8	11	34	36	70
Tulip poplar - oak	9	9	8	64	24	88
Tulip poplar - red maple	6	5	5	36	13	48
Mixed oak	10	10	7	74	26	99
Red maple	8	5	7	31	22	53
Overall	45	15	15	48	26	74

^a Based on the number of plots for each community, and all plots for overall.

Shrubs included arrowwood, blackberry-raspberry, blueberry, greenbriar spp., ironwood, Japanese barberry, mapleleaf viburnum, serviceberry, smooth blackhaw, rhododendron, rose spp., sassafras, spicebush, Tatarian honeysuckle and witch-hazel. Tree species included American beech, American elm, ash spp., black birch, black cherry, blackgum, black oak, chestnut oak, mazzard cherry, mockernut hickory, northern red oak, pignut hickory, red maple, white oak and yellow-poplar.

^b Based on the number of plots for each community and all plots for overall.

^c Density of shrub and tree stems may not equal total due to rounding.

Table 17. List of herbaceous broadleaf, grass (and grass-like) and vine species that were recorded on at least one of the 45 - 2.0 m² sample plots at Hopewell Furnace National Historic Site.

Broadleaf	Grass	Vine
Bedstraw	Bottlebrush grass	Bittersweet
Bellwort	An unknown	Grape spp.
Clearweed		Hog peanut
Enchanter's nightshade		Japanese honeysuckle
False Solomon's seal		Poison ivy
Hayscented fern		Virginia creeper
Jack-in-the-pulpit		
Lady's thumb		
Partridgeberry		
Rue anemone		
Skunk cabbage		
Strawberry		
An unknown		
Violet spp.		
Wild licorice		
White snakeroot		
Woodland agrimony		
Yellow wood sorrel		

Table 18. Number of 2.0 m² sample plots and number^a of species by herbaceous group^b and community at Hopewell Furnace National Historic Site.

Community	Sample Plots	Species Group			Total
		Broadleaf	Grass	Vine	
		(-----Number-----)			
Mixed oak - black birch	12	6	1	2	9
Tulip poplar - oak	9	9	2	5	16
Tulip poplar - red maple	6	13	1	6	20
Mixed oak	10	4	0	3	7
Red maple	8	12	2	3	17
Overall	45	18	2	6	26

^a Based on the number of plots for each community, and all plots for overall.

^b Broadleaves included bedstraw, bellwort, clearweed, enchanter's nightshade, false Solomon's seal, hayscented fern, Jack-in-the-pulpit, lady's thumb, partridgeberry, rue anemone, skunk cabbage, strawberry, an unknown, violet, wild licorice, white snakeroot, woodland agrimony and yellow wood sorrel. Grasses included bottlebrush grass and an unknown. Vines included bittersweet, grape, hog peanut, Japanese honeysuckle, poison ivy and Virginia creeper.

Table 19. Number of 2.0 m² sample plots and average^a coverage (%) by herbaceous group^b and community at Hopewell Furnace National Historic Site.

Community	Sample Plots (No.)	Coverage			Total
		Broadleaf	Grass	Vine	
		(-----%-----)			
Mixed oak - black birch	12	1	3	1	5
Tulip poplar - oak	9	15	<1	3	18
Tulip poplar - red maple	6	35	40	6	81
Mixed oak	10	7	0	<1	7
Red maple	8	15	68	2	85
Overall	45	12	18	2	32

^a Based on the number of plots for each community, and all plots for overall.

^b Broadleaves included bedstraw, bellwort, clearweed, enchanter's nightshade, false Solomon's seal, hayscented fern, Jack-in-the-pulpit, lady's thumb, partridgeberry, rue anemone, skunk cabbage, strawberry, unknown, violet, wild licorice, white snakeroot, woodland agrimony and yellow wood sorrel. Grasses included bottlebrush grass and unknown. Vines included bittersweet, grape, hog peanut, Japanese honeysuckle, poison ivy and Virginia creeper.

Table 20. Statistics from the 45 plot sample of number of shrub, tree and total species per 0.04 hectare plot and density of shrub, tree and total stems that were >150 cm in height and ≤10 cm in diameter at 1.3 m above ground, and sampling intensity to achieve 80, 90 and 95% probability by species group at Hopewell Furnace National Historic Site.

	Species			Stems		
	Shrub	Tree	Total	Shrub	Tree	Total
Statistics from the Sample	(---Number /Plot--)			(-----Stems/Hectare-----)		
Average	2.3	3.2	5.4	349	464	814
Standard Deviation	1.6	1.4	2.3	447	503	618
Standard Error	0.2	0.2	0.3	67	75	92
Confidence Interval @ 80% (±)	0.3	0.3	0.5	87	98	121
Confidence Interval @ 90% (±)	0.4	0.4	0.6	112	126	155
Confidence Interval @ 95% (±)	0.5	0.4	0.7	135	151	186
Sampling Intensity	(-----Number of 0.04 Hectare Plots-----)					
Sample Number @ 80%	21	9	8	70	50	25
Sample Number @ 90%	141	57	52	463	331	163
Sample Number @ 95%	814	327	299	2675	1911	940

Table 21. Statistics from the 45 plot sample of number of shrub, tree and total species per 0.04 hectare plot and density of shrub, tree and total stems that were >10 cm in diameter at 1.3 m above ground, and sampling intensity to achieve 80, 90 and 95% probability by species group at Hopewell Furnace National Historic Site.

	Species			Stems		
	Shrub	Tree	Total	Shrub	Tree	Total
Statistics from the Sample	(---Number/Plot---)			(-----Stems/Hectare-----)		
Average	0.4	4.4	4.6	10	430	440
Standard Deviation	0.5	1.6	1.8	29	105	107
Standard Error	0.1	0.2	0.3	4	16	16
Confidence Interval @ 80% ($\pm$)	0.1	0.3	0.4	6	20	21
Confidence Interval @ 90% ($\pm$)	0.1	0.4	0.5	7	26	27
Confidence Interval @ 95% ($\pm$)	0.1	0.5	0.6	9	32	32
Sampling Intensity	(-----Number of 0.04 Hectare Plots-----)					
Sample Number @ 80%	168	6	7	2360	3	3
Sample Number @ 90%	1108	39	45	7358	17	17
Sample Number @ 95%	6401	228	258	13632	97	96

Table 22. Statistics from the 45 plot sample of number of shrub, tree and total species per 2.0 m² plot and density of shrub, tree and total stems (x 1000) that were seedling-sized and sampling intensity to achieve 80, 90 and 95% probability by species group at Hopewell Furnace National Historic Site.

	Species			Stems		
	Shrub	Tree	Total	Shrub	Tree	Total
Statistics from the Sample	(---Number /Plot---)			(1000 Stems/Hectare)		
Average	1.9	2.2	4.0	48	26	74
Standard Deviation	1.1	1.3	2.0	57	19	56
Standard Error	0.2	0.2	0.9	9	3	8
Confidence Interval @ 80% ($\pm$)	0.2	0.2	0.3	11	4	11
Confidence Interval @ 90% ($\pm$)	0.3	0.3	0.4	14	5	14
Confidence Interval @ 95% ($\pm$)	0.3	0.4	0.5	17	6	17
Sampling Intensity	(-----Number of 2.0 ² m Plots-----)					
Sample Number @ 80%	13	15	7	61	24	25
Sample Number @ 90%	84	96	48	401	157	163
Sample Number @ 95%	484	552	279	2316	907	943

Table 23. Statistics from the 45 plot sample of number of herbaceous species per 2.0 m² plot by herbaceous group, and sampling intensity to achieve 80, 90 and 95% probability by herbaceous group at Hopewell Furnace National Historic Site.

	Species Group			Total
	Broadleaf	Grass	Vine	
Statistics from the Sample	(-----Number of Species/Plot-----)			
Average	2.2	0.6	0.9	3.7
Standard Deviation	2.3	0.9	1.1	3.7
Standard Error	0.3	0.1	0.2	0.5
Confidence Interval @ 80% (±)	0.5	0.2	0.2	0.7
Confidence Interval @ 90% (±)	0.6	0.2	0.3	0.9
Confidence Interval @ 95% (±)	0.7	0.3	0.3	1.1
Sampling Intensity	(-----Number of 2.0 ² m Plots-----)			
Sample Number @ 80%	46	97	62	41
Sample Number @ 90%	304	640	410	273
Sample Number @ 95%	1756	3696	2368	1578

Table 24. Statistics from the 45 plot sample of coverage per plot by herbaceous group and sampling intensity to achieve 80, 90 and 95% probability by herbaceous group at Hopewell Furnace National Historic Site.

	Coverage			Total
	Broadleaf	Grass	Vine	
Statistics from the Sample	(-----(%/Plot)-----)			
Average	12	18	2	32
Standard Deviation	19	33	3	42
Standard Error	3	5	1	6
Confidence Interval @ 80% (±)	4	7	1	8
Confidence Interval @ 90% (±)	5	8	1	11
Confidence Interval @ 95% (±)	6	10	9	13
Sampling Intensity	(-----Number of 2.0 ² m Plots-----)			
Sample Number @ 80%	106	143	102	74
Sample Number @ 90%	698	940	671	489
Sample Number @ 95%	4030	5428	3873	2824

>10 cm in diameter (Table 25). Increasing the number of plots sampled to 168 would be expected to achieve $\geq 80\%$ level of confidence for all parameters, except density of shrub species stems that were >10 cm in diameter (Table 25).

The level of confidence of estimating the seedling-sized and herbaceous plants was determined for the same number (70 and 168) and twice the number (140 and 336) of 0.04 hectare overstory plots (Table 25). Inventorying seedling-sized stems on 70 - 2.0 m² plots would be expected to have $\geq 80\%$ level of confidence for all parameters. Inventorying the number of species and coverage of broadleaf, grass, vine and total herbaceous plants on 70 - 2.0 m² plots would be expected to have >80% level of confidence for 3 of the 8 parameters (Table 24). Increasing the number of plots to 143 would provide 80% level of confidence for all herbaceous parameters.

Numbers of plots and hours of effort required to collect, analyze and summarize overstory and understory data collected as part of a potential long-term forest monitoring program at the Hopewell Furnace National Historic Site are presented in Table 26. The minimum total time to inventory the 70 - 0.04 ha overstory plots and 70 - 2.0 m² understory plots in the forest communities was estimated to be 241.50 person-hours. Increasing the number of 0.04 hectare and 2.0 m² plots to 168, each, would increase the time required to 579.60 person-hours. These 168 plots would be expected to achieve $\geq 80\%$ level of confidence in estimating the mean of all overstory and understory parameters, except density of shrub species stems that were >10 cm in diameter. A third alternative would be to inventory the overstory with 70 - 0.04 hectare plots and inventory the understory with 140 - 2.0 m² plots. This alternative would require 371.00 person-hours of effort. It would result in estimating all parameters at $\geq 80\%$ level of confidence, except the number of shrub species per plot and density of shrub species stems in the >10 cm diameter class. We believe the 70 sample points, each with 1 - 0.04 hectare plot for the sapling-sized and tree-sized parameters and 2 - 2.0 m² plots for the seedling-sized and herbaceous plant parameters would provide the best balance of precision and effort. This inventory plan conducted in forest communities similar to those in this study data set should provide Hopewell Furnace National Historic Site with an adequate database for establishing a comprehensive long-term monitoring program.

Numbers of sample plots to inventory the number of shrub, tree and total species per plot and density of shrub, tree and total stems, by community, to achieve 80% probability by species group are presented in Appendix III. These values are presented to provide an estimate on the community specific sample inventory requirements. These values should be viewed only in a general sense because the procedures used in this study were to provide site-wide information and not community specific information.

Table 25. Probability of estimating average number of species and densities of stems for 1-to-10 cm and >10 cm in diameter at 1.3 m above ground (overstory) and seedling-sized stems (stems ≤ 150 cm in height) for shrub and tree species, and average numbers of herbaceous species and coverage values from selected numbers of sample plots in communities similar to those sampled in this study at Hopewell Furnace National Historic Site.

Component	Number of Plots	Variable	Stems 1 to 10 cm			Stems >10 cm			
			Shrub	Tree	Total	Shrub	Tree	Total	
(-----Probability %-----)									
Overstory	70	No. Species	80	90	90	<80	90	90	
		No. Stems	80	80	80	<80	90	90	
	168	No. Species	90	90	90	80	90	90	
		No. Stems	80	80	90	<80	95	95	

Variable			Shrub	Tree	Total				
(-----Probability %-----)									
Seedlings	70	No. Species	80	80	90				
		No. Stems	80	80	80				
	140	No. Species	90	90	90				
		No. Stems	80	80	80				
	168	No. Species	90	90	90				
		No. Stems	80	90	90				
	336	No. Species	90	90	90				
		No. Stems	80	90	90				

	Variable			Species Group					
				Broadleaf	Grass	Vine	Total		
	(-----Probability %-----)								
Herbaceous	70	No. Species	80	<80	80	80			
		Coverage	<80	<80	<80	<80			
	140	No. Species	80	80	80	80			
		Coverage	80	80	80	80			
	168	No. Species	80	80	80	80			
		Coverage	80	80	80	80			
	336	No. Species	80	80	80	80			
		Coverage	80	80	80	80			

Table 26. Numbers of plots and hours of effort required to collect, analyze and summarize overstory and understory data collected as part of a potential long-term forest monitoring program at the Hopewell Furnace National Historic Site.

Overstory		Seedling		Herbaceous		Total Hours
Number of Plots	Hours ^a	Number of Plots	Hours ^b	Number of Plots	Hours ^c	
70	112.00	70	70.00	70	59.50	241.50
70	112.00	140	140.00	140	119.00	371.00
168	268.00	168	168.00	168	142.80	579.60
168	268.00	336	336.00	336	285.60	890.40

^a It was estimated to take 1.6 person-hours per plot to locate, inventory the sapling-sized and tree-sized shrub and tree stems on a 0.04 ha plot, enter the data into a computer file and summarize the information.

^b It was estimated to take 1.0 person-hours per plot to locate, inventory the seedling-sized shrub and tree stems on a 2.0 m² plot, enter the data into a computer file and summarize the information.

^c It was estimated to take 0.85 person-hours per plot to locate, inventory the herbaceous plants on a 2.0 m² plot, enter the data into a computer file and summarize the information. This assumes that the plot would be the same as for the seedling-sized inventory.

Valley Forge National Historical Park

Sapling-sized and Tree-sized Stems

For stems that were >150 cm in height, 18 shrub species and 32 tree species were inventoried on the 49 - 0.04 ha sample plots (Tables 2 and 27). The greatest number of shrub species (9 species) occurred in the Wayne's Woods community. Tree and total species (17 and 25 species, respectively) were greatest in the Mount Joy community. The lowest number of shrub species was 3, occurring in the Post Office community. The River - Railroad community had the lowest numbers of tree and total species (6 and 12 species, respectively).

The areas inventoried at this historical park had the greatest density of shrub and tree species stems in the smaller diameter classes. For shrub species (Table 28), the overall average density of sapling-sized stems (<10 cm in diameter) was 1126/ha (96% of stems), and the overall average density of tree-sized stems (>10 cm in diameter) was 51/ha (4% of stems). For the Washington Chapel, River - Railroad, Railroad - River, Post Office, Basin 21, Wayne's Woods, Mount Misery and Mount Joy communities, 94, 93, 80, 96, 71, 98, 97 and 95%, respectively, of shrub species stems were <10 cm in diameter, with the majority of stems (83, 55, 46, 79, 45, 96, 84 and 63%, respectively) in the 1 - 5 cm diameter class. For tree species (Table 28), the overall average density of sapling-sized stems was 376/ha (52% of stems), and the overall average density of tree-sized stems was 349/ha (48% of stems). For the Washington Chapel, River - Railroad, Railroad - River, Post Office, Basin 21, Wayne's Woods, Mount Misery and Mount Joy communities, 52, 20, 42, 55, 48, 14, 65 and 55%, respectively, of tree species stems were <10 cm in diameter. The greatest amount of tree species stems occurred in the 6 - 10 cm diameter class for the Railroad - River, Post Office, Basin 21, Mount Misery and Mount Joy communities (34, 30, 33, 37 and 35% of stems, respectively). The greatest amount of tree species stems (35% of stems) occurred in the 1 - 5 cm diameter class for the Washington Chapel community, and the River - Railroad community had the greatest density of stems (18%) in the 16 - 20 cm diameter class. For the Wayne's Woods community, tree species stem amount was greatest in the 56 - 60 and in the 66 - 70 cm diameter classes, each containing 12% of stems. The overall total average density of sapling-sized shrub and tree species combined stems (Table 28) was 1502/ha (79% of stems), and the total overall average density of tree-sized combined stems was 397/ha (21% of stems). The Washington Chapel, River - Railroad, Railroad - River, Post Office, Basin 21, Wayne's Woods, Mount Misery and Mount Joy communities had 83, 61, 53, 75, 51, 94, 80 and 77%, respectively, of total shrub and tree species combined stems <10 cm in diameter. The greatest average density of total shrub and tree species combined stems occurred in the 1 - 5 cm diameter class for the Washington Chapel, River - Railroad, Post Office, Wayne's Woods, Mount Misery and Mount Joy communities (70, 33, 52, 92, 55 and 43% of stems, respectively). Within the Railroad - River and Basin 21 communities, the greatest average amount of total shrub and tree species combined stems (34 and 32%, respectively) occurred in the 6 - 10 cm diameter class.

The overall number of sapling-sized shrub species was 18 (Table 29). Spicebush and viburnum were the most abundant species, with overall average densities of 278 and 231 stems/ha, respectively. Within the individual communities, the most abundant species were dogwood (900 stems/ha) and spicebush (133 stems/ha) in the Washington Chapel community, other shrubs, including apple, bladdernut, eastern redbud, hackberry, hawthorn, ironwood and unknown, (288 stems/ha) and spicebush (106 stems/ha) in the River - Railroad community, spicebush and other

Table 27. List of shrub and tree species for stems >150 cm in height and ≥ 1 cm in diameter at 1.3 m above ground that were recorded on at least one of the 49 - 0.04 hectare sample plots at Valley Forge National Historical Park.

<u>Shrub Species</u>	<u>Tree Species</u>
Apple	American beech
Bladdernut	American elm
Boxelder	Ash spp.
Dogwood spp.	Bitternut hickory
Eastern redbud	Blackgum
Flowering dogwood	Black cherry
Hackberry	Black locust
Hawthorn	Black oak
Ironwood	Black walnut
Mapleleaf viburnum	Butternut
Mountain laurel	Chestnut oak
Privet	Eastern cottonwood
Smooth blackhaw	Eastern white pine
Sassafras	Hemlock
Spicebush	Magnolia spp.
Tatarian honeysuckle	Mazzard cherry
An unknown	Mockernut hickory
Witch-hazel	Northern catalpa
	Northern red oak
	Norway maple
	Pin oak
	Red maple
	River birch
	Scarlet oak
	Shagbark hickory
	Silver maple
	Slippery elm
	Sugar maple
	Tree-of-heaven
	White oak
	Willow spp.
	<u>Yellow-poplar</u>

Table 28. Average^a density of stems >150 cm in height by diameter class and community for shrub, tree and total species groups at Valley Forge National Historical Park.

Species Group	Diameter Class (cm)														
Community	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	>70
Shrub	(-----Stems per Hectare-----)														
Washington Chapel	1050	146	54	13	4										
River - Railroad	294	200	25	6	6										
Railroad - River	156	113	56	13											
Post Office	533	108	25			4									
Basin 21	79	46	29	13	4	4									
Wayne's Woods	4033	71	33	50											
Mount Misery	911	144	22	8											
Mount Joy	509	266	28			3	3	3							
Overall	985	141	33	12	2	2	1	1							
Tree															
Washington Chapel	167	83	21	29	17	29	33	4	29	13	8	25	4	4	13
River - Railroad	13	69	56	75	44	31	31	31	13	31	13				6
Railroad - River	63	275	163	125	31	56	25	25	19	13		6	6		
Post Office	175	204	71	33	33	17	25	50	25	29	8	4	4	8	
Basin 21	167	363	213	125	100	79	29	13	8	13			4		
Wayne's Woods	8	21	4	4		8	17	17	17	13	21	25	17	25	17
Mount Misery	311	431	139	78	31	11	53	33	22	14	6	14	8		
Mount Joy	131	234	100	44	19	25	22	19	6	9	9	19	9	6	6
Overall	148	228	97	61	33	30	31	24	17	16	8	13	7	6	6

Table 28. Continued.

Species Group Community	Diameter Class (cm)														
	1-5	6-10	11-15	16-20	21-25	26-30	31-35	36-40	41-45	46-50	51-55	56-60	61-65	66-70	>70
Total ^b	(-----Stems per Hectare-----)														
Washington Chapel	1217	229	75	42	21	29	33	4	29	13	8	25	4	4	13
River - Railroad	307	269	81	81	50	31	31	31	13	31	13				6
Railroad - River	219	388	219	138	31	56	25	25	19	13		6	6		
Post Office	708	312	96	33	33	21	25	50	25	29	8	4	4	8	
Basin 21	246	409	242	138	104	83	29	13	8	13			4		
Wayne's Woods	4041	92	37	54		8	17	17	17	13	21	25	17	25	17
Mount Misery	1222	575	161	86	31	11	53	33	22	14	6	14	8		
Mount Joy	640	500	128	44	19	28	25	22	6	9	9	19	9	6	9
Overall	1133	369	130	73	35	32	32	25	17	16	8	13	7	6	6

^a Based on the number of plots for each community, and all plots for overall.

^b Average density of stems by species groups within community may not add up to total due to rounding.

Table 29. Number of 0.04 hectare sample plots^a, shrub species^b and average^a density of shrub species stems that were >150 cm in height and ≤10 cm in diameter at 1.3 m above ground, by species group^c and community at Valley Forge National Historical Park.

Community	Sample Plots	Species	Box- elder	Dog- wood	Witch- hazel	Mountain laurel	Spice- bush	Sassa- fras	Vibru- num	Other Shrubs	Non- native	Total ^d
	(--Number--)		(-----Stems per Hectare-----)									
Washington Chapel	6	7	0	900	0	0	133	0	79	42	42	1196
River - Railroad	4	6	0	44	0	0	106	13	44	288	0	494
Railroad - River	4	7	13	31	0	0	106	0	13	106	0	269
Post Office	6	3	21	263	0	0	358	0	0	0	0	642
Basin 21	6	5	42	46	0	0	25	0	8	4	0	125
Wayne's Woods	6	8	0	54	0	0	1546	0	1604	600	300	4104
Mount Misery	9	7	0	0	314	586	11	53	47	33	11	1056
Mount Joy	8	8	0	203	9	447	34	9	63	0	9	775
Overall	49	18	9	194	59	181	278	12	231	117	45	1126

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall.

^c Dogwood included dogwood spp. and flowering dogwood; Viburnum included mapleleaf viburnum and smooth blackhaw; Other Shrubs included apple, bladdernut, eastern redbud, hackberry, hawthorn, ironwood and an unknown; Non-native were privet and Tatarian honeysuckle.

^d Average density of stems by species groups within community may not add up to total due to rounding.

shrubs (both 106 stems/ha) in the Railroad - River community, spicebush (358 stems/ha) and dogwood (263 stems/ha) in the Post Office community, dogwood (46 stems/ha) and boxelder (42 stems/ha) in the Basin 21 community, viburnum (1,604 stems/ha) and spicebush (1,546 stems/ha) in the Wayne's Woods community, mountain laurel (586 stems/ha) and witch-hazel (314 stems/ha) in the Mount Misery community, and mountain laurel (447 stems/ha) and dogwood (203 stems/ha) in the Mount Joy community. The overall number of sapling-sized tree species was 24 (Table 30). Maple (114 stems/ha) and blackgum (83 stems/ha) were the most abundant species over the eight communities. The dominant species within communities were cherry (167 stems/ha) and other trees, including American beech, black walnut, magnolia spp., river birch, tree-of-heaven and willow spp., (29 stems/ha) in the Washington Chapel community, ash and cherry (both 25 stems/ha) in the River - Railroad community, ash (125 stems/ha) and elm (94 stems/ha) in the Railroad - River community, maple (171 stems/ha) and cherry (67 stems/ha) in the Post Office community, elm (142 stems/ha) and ash (121 stems/ha) in the Basin 21 community, maple (29 stems/ha) in the Wayne's Woods community, blackgum (339 stems/ha) and maple (236 stems/ha) in the Mount Misery community, and maple (188 stems/ha) and blackgum (75 stems/ha) in the Mount Joy community.

The overall number of tree-sized shrub species was 6 (Table 31). The most abundant species were dogwood and spicebush, with overall average densities of 18 and 14 stems/ha, respectively. The most abundant species for the individual communities were dogwood (63 stems/ha) and sassafras (8 stems/ha) in the Washington Chapel community, boxelder (19 stems/ha) and dogwood (13 stems/ha) in the River - Railroad community, apple (31 stems/ha) and spicebush (25 stems/ha) in the Railroad - River community, dogwood (17 stems/ha) and spicebush (8 stems/ha) in the Post Office community, sassafras (38 stems/ha) and boxelder (8 stems/ha) in the Basin 21 community, spicebush (67 stems/ha) and dogwood (17 stems/ha) in the Wayne's Woods community, sassafras (19 stems/ha) and spicebush (11 stems/ha) in the Mount Misery community, and dogwood (28 stems/ha) and spicebush (6 stems/ha) in the Mount Joy community. The overall number of tree-sized tree species was 30 (Table 32). Across all communities, the most abundant species were yellow poplar and oak (79 and 64 stems/ha, respectively). Within communities, the dominant species were oak (71 stems/ha) and yellow poplar (63 stems/ha) in the Washington Chapel community, yellow poplar (119 stems/ha) and ash (106 stems/ha) in the River - Railroad community, ash (206 stems/ha) and maple (100 stems/ha) in the Railroad - River community, yellow poplar (125 stems/ha) and ash (50 stems/ha) in the Post Office community, other trees, including American beech, black locust, black walnut, butternut, eastern cottonwood, eastern white pine, hemlock, northern catalpa, river birch, tree-of-heaven and willow spp., (263 stems/ha) and maple (138 stems/ha) in the Basin 21 community, yellow poplar (133 stems/ha) and ash (21 stems/ha) in the Wayne's Woods community, oak (197 stems/ha) and yellow poplar (83 stems/ha) in the Mount Misery community, and oak (88 stems/ha) and maple (81 stems/ha) in the Mount Joy community.

Summary data of sapling-sized and tree-sized shrub and tree species and stems are provided in Tables 33 and 34).

Seedling-sized Stems

For stems <150 cm in height (seedling-sized stems), 16 shrub species and 15 tree species were recorded on the 49 - 2.0 m² sample plots (Table 35 and 36). The greatest numbers of shrub and total species (7 and 15 species, respectively) occurred in the Washington Chapel community

Table 30. Number of 0.04 hectare sample plots^a, tree species^b and average^a density of tree species stems that were >150 cm in height and ≤10 cm in diameter at 1.3 m above ground, by species group^c and community at Valley Forge National Historical Park.

Community	Sample Plots	Species	Maple	Elm	Hickory	Ash	Yellow- poplar	Black- gum	Cherry	Oak	Other Tree	Total ^d
	(-Number-)		(-----Stems per Hectare-----)									
Washington Chapel	6	10	21	4	8	8	0	4	167	8	29	250
River - Railroad	4	5	6	13	13	25	0	0	25	0	0	81
Railroad - River	4	9	31	94	6	125	50	0	19	6	6	338
Post Office	6	13	171	50	13	13	50	0	67	13	4	379
Basin 21	6	10	83	142	0	121	0	67	4	0	113	529
Wayne's Woods	6	1	29	0	0	0	0	0	0	0	0	29
Mount Misery	9	7	236	0	3	0	111	339	8	33	11	742
Mount Joy	8	12	188	0	22	6	34	75	3	34	3	366
Overall	49	24	114	33	8	31	36	83	35	15	21	376

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall

^c Maple included Norway, red, silver and sugar; Elm included American and slippery; Hickory included bitternut, mockernut and shagbark; Ash included green and white; Cherry included black and mazzard; Oak included black, chestnut, northern red and scarlet; Other Tree included American beech, black walnut, magnolia spp., river birch, tree-of-heaven and willow spp.

^d Average density of stems by species groups within community may not add up to total due to rounding.

Table 31. Number of 0.04 hectare sample plots^a, shrub species^b and average^c density of shrub species stem that were >10 cm in diameter at 1.3 m above ground, by species^b and community at Valley Forge National Historical Park.

Community	Sample Plots	Species	Apple	Box- elder	Dog- wood	Sassa- fras	Spice- bush	Total ^d
	(Number)		(-----Stems per Hectare-----)					
Washington Chapel	6	3	0	0	63	8	0	71
River - Railroad	4	3	0	19	13	6	0	38
Railroad - River	4	3	31	0	0	13	25	69
Post Office	6	3	0	4	17	0	8	29
Basin 21	6	3	0	8	4	38	0	50
Wayne's Woods	6	2	0	0	17	0	67	83
Mount Misery	9	2	0	0	0	19	11	31
Mount Joy	8	3	0	0	28	3	6	38
Overall	49	6	3	3	18	11	14	49

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall.

^c Dogwood included dogwood spp. and flowering dogwood.

^d Average density of stems by species groups within community may not add up to total due to rounding.

Table 32. Number of 0.04 hectare sample plots^a, tree species^b and average^a density of tree species stems that were >10 cm in diameter at 1.3 m above ground, by species group^c and community at Valley Forge National Historical Park.

Community	Sample Plots	Species	Maple	Elm	Hickory	Ash	Yellow- poplar	Black- gum	Cherry	Oak	Other Tree	Total ^d
	(--Number--)		(-----Stems per Hectare-----)									
Washington Chapel	6	11	17	4	17	8	63	25	0	71	29	233
River - Railroad	4	6	31	25	38	106	119	0	6	0	0	325
Railroad - River	4	10	100	44	13	206	50	0	19	19	19	469
Post Office	6	12	42	21	4	50	125	0	8	21	38	308
Basin 21	6	12	138	38	0	113	4	29	0	0	263	583
Wayne's Woods	6	6	0	0	8	21	133	0	4	8	8	183
Mount Misery	9	9	58	0	0	0	83	64	0	197	6	408
Mount Joy	8	15	81	0	6	3	63	34	3	88	19	297
Overall	49	30	59	13	9	49	79	24	4	64	47	348

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall.

^c Maple included Norway, red, silver and sugar; Elm included American and slippery; Hickory included mockernut and shagbark; Ash included green and white; Cherry included black and mazzard; Oak included black, chestnut, northern red, pin, scarlet and white; Other Tree included American beech, black locust, black walnut, butternut, eastern cottonwood, eastern white pine, hemlock, northern catalpa, river birch, tree-of-heaven and willow spp.

^d Average density of stems by species groups within community may not add up to total due to rounding.

Table 33. Number of 0.04 hectare sample plots, number of shrub and tree species^a and average^b density of shrub and tree species stems that were >150 cm in height and ≤10 cm in diameter at 1.3 m above ground, by community at Valley Forge National Historical Park.

Community	Sample	Species		Stems		Total ^c
	Plots	Shrubs	Trees	Shrub	Tree	
	(-----Number-----)			(-----Stems per Hectare-----)		
Washington Chapel	6	7	10	1196	250	1446
River - Railroad	4	6	5	494	81	575
Railroad - River	4	7	9	269	338	606
Post Office	6	3	13	642	379	1021
Basin 21	6	5	10	125	529	654
Wayne's Woods	6	8	1	4104	29	4133
Mount Misery	9	7	7	1056	742	1797
Mount Joy	8	8	12	775	366	1141
Overall	49	18	24	1126	376	1501

^a Based on the number of plots for each community, and total number of plots for overall. Shrubs included apple, bladdernut, boxelder, dogwood spp., eastern redbud, flowering dogwood, hackberry, hawthorn, ironwood, mapleleaf viburnum, mountain laurel, privet, sassafras, smooth blackhaw, spicebush, Tatarian honeysuckle, an unknown and witch-hazel. Tree species included American beech, American elm, ash spp., blackgum, black cherry, black oak, black walnut, bittersweet hickory, chestnut oak, magnolia spp., mazzard cherry, mockernut hickory, Norway maple, and northern red oak, red maple, river birch, scarlet oak, silver maple, shagbark hickory, slippery elm, sugar maple, tree-of-heaven, willow spp. and yellow-poplar.

^b Based on the number of plots for each community and all plots for overall.

^c Density of shrub and tree stems may not equal total due to rounding.

Table 34. Number of 0.04 hectare sample plots, number of shrub and tree species^a and average^b density of shrub and tree species stem that were >10 cm in diameter at 1.3 m above ground by community at Valley Forge National Historical Park.

Community	Sample	Species		Stems		Total ^c
	Plots	Shrubs	Trees	Shrub	Tree	
	(-----Number-----)			(---Number per Hectare---		
Washington Chapel	6	3	11	71	233	304
River - Railroad	4	3	6	38	325	363
Railroad - River	4	3	10	69	469	538
Post Office	6	3	12	29	308	338
Basin 21	6	3	12	50	583	633
Wayne's Woods	6	2	6	83	183	267
Mount Misery	9	2	9	31	408	439
Mount Joy	8	3	15	38	297	334
Overall	49	6	29	49	348	397

^a Based on the number of plots for each community, and total number of plots for overall. Shrubs included apple, boxelder, dogwood spp., flowering dogwood, sassafras and spicebush. Tree species included American beech, American elm, ash spp. black cherry, black oak, black locust, black walnut, butternut, chestnut oak, eastern cottonwood, eastern white pine, magnolia spp., hemlock, mazzard cherry, mockernut hickory, Norway maple, northern catalpa, northern red oak, pin oak, red maple, river birch, scarlet oak, silver maple, shagbark hickory, slippery elm, sugar maple, tree-of-heaven, white oak and willow spp.

^b Based on the number of plots for each community and all plots for overall.

^c Density of shrub and tree stems may not equal total due to rounding.

Table 35. List of shrub and tree species for stems ≤ 150 cm in height that were recorded on at least one of the 49 - 2.0 m² sample plots at Valley Forge National Historical Park.

Shrub Species	Tree Species
Blackberry-raspberry	Ash spp.
Blueberry	Bitternut hickory
Boxelder	Black birch
Dogwood spp.	Black cherry
Flowering dogwood	Blackgum
Mapleleaf viburnum	Black oak
Mountain laurel	Chestnut oak
Poison ivy	Hickory spp.
Privet	Mazzard cherry
Rhododendron	Northern red oak
Rose spp.	Norway maple
Sassafras	Red maple
Smooth blackhaw	Slippery elm
Spicebush	Sugar maple
Wineberry	Yellow-poplar
Witch-hazel	

Table 36. Number of 2.0 m² sample plots and number of shrub, tree and total species^a for stems that were ≤150 cm in height by community at Valley Forge National Historical Park.

Community	Sample Plots (No.)	Shrub (-----Number of Species-----)	Species Tree	Total
Washington Chapel	6	7	8	15
River - Railroad	4	4	5	9
Railroad - River	4	5	0	5
Post Office	6	4	7	11
Basin 21	6	1	1	2
Wayne's Woods	6	3	3	6
Mount Misery	9	6	8	14
Mount Joy	8	6	3	9
Overall	49	16	15	31

^a Occurred at least once in the specific community or at least once on all plots for overall.

(Table 36). The Washington Chapel and Mount Misery communities had the greatest number of tree species (both 8 species). The Basin 21 community had the lowest numbers of shrub and total species (1 and 2 species, respectively). No tree species were recorded in the Railroad - River community.

The overall average density of seedling-sized shrub stems was 27,000/ha, with 96% of stems in the 1 - 50 cm height class (Table 37). The Washington Chapel, River - Railroad, Railroad - River, Post Office, Basin 21, Wayne's Woods, Mount Misery and Mount Joy communities had 98, 100, 100, 90, 100, 88, 100 and 100%, respectively, of shrub species stems in the 1 - 50 cm height class. For seedling-sized trees species, the overall average density of stems was 17,000/ha, with about 94% of stems in the 1 - 50 cm height class (Table 37). For the Washington Chapel, River - Railroad, Post Office, Basin 21, Wayne's Woods, Mount Misery and Mount Joy communities, respectively, 100, 100, 100, 100, 100, 96 and 100% of tree species stems occurred in the 1 - 50 cm height class. For total seedling-sized shrubs and trees (Table 37), the overall average density of stems was 43,000/ha, with 98% occurring in the 1 - 50 cm height class. The Washington Chapel, River - Railroad, Railroad - River, Post Office, Basin 21, Wayne's Woods, Mount Misery and Mount Joy communities, respectively, had 99, 100, 100, 95, 100, 90, 98 and 100% of total stems in the 1 - 50 cm height class.

Table 37. Number of 2.0 m² sample plots and average density^a of seedling-sized (stems ≤150 cm in height) shrub, tree and total species^b stems (x 1000) by height class and community at Valley Forge National Historical Park.

Community	Sample Plots (No.)	Shrubs		Trees		Total ^c	
		Height Class		Height Class		Height Class	
		1-50	51-150	1-50	51-150	1-50	51-150
(-----1000 Stems per Hectare-----)							
Washington Chapel	6	41	1	40	0	81	1
River - Railroad	4	23	0	9	0	31	0
Railroad - River	4	26	0	0	0	26	0
Post Office	6	28	3	32	0	60	3
Basin 21	6	1	0	1	0	2	0
Wayne's Woods	6	23	3	5	0	28	3
Mount Misery	9	38	0	24	1	63	1
Mount Joy	8	24	0	6	0	29	0
Overall	49	26	1	16	<1	42	1

^a Based on the number of plots for each community and all plots for overall.

^b Shrubs included blackberry-raspberry, blueberry, boxelder, dogwood spp., flowering dogwood, mapleleaf viburnum, mountain laurel, poison ivy, privet, rhododendron, rose spp., sassafras, smooth blackhaw, spicebush, wineberry and witch-hazel. Tree species included ash spp., bitternut hickory, black birch, black cherry, blackgum, black oak, chestnut oak, hickory spp., mazzard cherry, northern red oak, Norway maple, red maple, slippery elm, sugar maple and yellow-poplar.

^c Density of shrub and tree stems may not equal total due to rounding.

Of the seedling-sized shrub species (Table 38), spicebush (overall average of 7,000 stems/ha) and blackberry and viburnum (both overall average of 5,000 stems/ha) were most abundant. Within communities, the dominant species were viburnum (21,000 stems/ha) and blackberry (9,000 stems/ha) in the Washington Chapel community, spicebush (13,000 stems/ha) and blackberry (8,000 stems/ha) in the River - Railroad community, blackberry (12,000 stems/ha) and spicebush (9,000 stems/ha) in the Railroad - River community, spicebush (16,000 stems/ha) and blackberry

Table 38. Number of 2.0 m² sample plots^a, shrub species^b and average^a density of shrub seedling-sized (stems ≤150 cm in height) stems (x 1000), by species group^c and community at Valley Forge National Historical Park.

Community	Sample Plots	Species	Black- berry	Blue- berry	Spice- bush	Sassa- fras	Vibru- num	Other Shrubs	Non- native	Total ^d
	(--Number--)		(-----1000 Stems per Hectare-----)							
Washington Chapel	6	7	9	0	4	0	21	8	0	42
River - Railroad	4	4	8	0	13	0	0	0	3	23
Railroad - River	4	5	12	0	9	0	1	0	5	26
Post Office	6	4	10	0	16	0	0	3	3	32
Basin 21	6	1	0	0	0	1	0	0	0	1
Wayne's Woods	6	3	1	0	23	0	2	0	0	26
Mount Misery	9	6	0	16	0	7	9	7	0	38
Mount Joy	8	6	6	9	2	6	1	1	0	24
Overall	49	16	5	4	7	2	5	3	1	27

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall.

^c Blackberry included blackberry, raspberry and wineberry; Viburnum included mapleleaf viburnum and smooth blackhaw; Other Shrubs included boxelder, dogwood spp., flowering dogwood, mountain laurel, poison ivy, rhododendron and witch-hazel; Non-native included privet and rose spp.

^d Average density of stems by species groups within community may not add up to total due to rounding.

(10,000 stems/ha) in the Post Office community, sassafras (1,000 stems/ha) in the Basin 21 community, spicebush (23,000 stems/ha) and viburnum (2,000 stems/ha) in the Wayne's Woods community, blueberry (16,000 stems/ha) and viburnum (9,000 stems/ha) in the Mount Misery community, and blueberry (9,000 stems/ha) and blackberry and sassafras (both 6,000 stems/ha) in the Mount Joy community. Of the seedling-sized tree species, ash (5,000 stems/ha) and cherry and oak (both 3,000 stems/ha) were most abundant (Table 39). For the individual communities, the most abundant species were ash (21,000 stems/ha) and cherry (8,000 stems/ha) in the Washington Chapel community, cherry (4,000 stems/ha) and yellow poplar (3,000 stems/ha) in the River - Railroad community, ash (16,000 stems/ha) and cherry (8,000 stems/ha) in the Post Office community, ash (1,000 stems/ha) in the Basin 21 community, yellow poplar (3,000 stems/ha) and ash (2,000 stems/ha) in the Wayne's Woods community, oak (14,000 stems/ha) and blackgum (6,000 stems/ha) in the Mount Misery community, and yellow poplar (4,000 stems/ha) and maple and slippery elm (both 1,000 stems/ha) in the Mount Joy community.

Summary data of seedling-sized shrub and tree species and stems are provided in Table 40.

Herbaceous

A total of 16 broadleaf, 2 grass, and 5 vine species were inventoried on the 49 - 2.0 m² sample plots (Table 41 and 42). The Mount Joy community (Table 42) had the greatest numbers of broadleaf and total species (8 and 13 species, respectively). One grass species occurred in the Washington Chapel, River - Railroad, Railroad - River, Basin 21 and Mount Joy communities. Vine species were greatest (4 species) in the Washington Chapel, Post Office, Wayne's Woods and Mount Joy communities. The Mount Misery community had the lowest numbers of broadleaf (2) and total (3) species. No grass species were recorded in the Post Office, Wayne's Woods and Mount Misery communities. Vine species were lowest (1 species) in the Railroad - River and Mount Misery communities.

The overall average percent coverage of broadleaves, grasses, vines, and total was 20, 18, 5, and 43%, respectively (Table 43). Broadleaf coverage was greatest (54% coverage) in the Wayne's Woods community. Grass (58%) and total (75%) coverage was greatest in the Basin 21 community. Vine coverage was greatest (11%) in the Railroad - River community. The Mount Misery community had the lowest broadleaf, vine, and total coverage (4, <1 and 4%, respectively).

Inventory Requirements

Selected for number of shrub, tree and total species per plot; and density of shrub, tree and total stems, and sampling intensity needed to achieve 80, 90 and 95% probability by species group were calculated for tree-, sapling- and seedling-sized components. Values for tree-, sapling- and seedling-sized components are presented in Tables 44, 45 and 46, respectively. Selected statistics for number of herbaceous species and herbaceous coverage per 2.0 m² plot by herbaceous group, and sampling intensity needed to achieve 80, 90 and 95% probability by herbaceous group are presented in Table 47 and Table 48, respectively.

The 0.04 hectare plot was considered to be the primary basis for selecting the number of plots needed to precisely determine the population means of the interested parameters of the forested

Table 39. Number of 2.0 m² sample plots^a, tree species^b and average^a density of tree seedling-sized (stems ≤150 cm in height) stems (x 1000), by species group^c and community at Valley Forge National Historical Park.

Community	Sample Plots	Species	Maple	Black Birch	Hickory	Ash	Yellow- poplar	Black- gum	Cherry	Oak	Slippery Elm	Total ^d Tree
	(-Number-)		(-----1000 Stems per Hectare-----)									
Washington Chapel	6	8	2	0	2	21	3	1	8	3	0	40
River - Railroad	4	5	0	0	1	1	3	0	4	0	0	9
Railroad - River	4	0	0	0	0	0	0	0	0	0	0	0
Post Office	6	7	3	0	2	16	2	0	8	0	2	32
Basin 21	6	1	0	0	0	1	0	0	0	0	0	1
Wayne's Woods	6	3	0	0	0	2	3	0	1	0	0	5
Mount Misery	9	8	1	1	0	0	2	6	2	14	0	25
Mount Joy	8	3	1	0	0	0	4	0	0	0	1	6
Overall	49	15	1	<1	1	5	2	1	3	3	<1	16

^a Based on the number of plots for each community, and all plots for overall.

^b Total number of individual species recorded in each community and all plots for overall

^c Maple included Norway, red and sugar; Hickory included bitternut and hickory spp.; Ash included green and white; Cherry included black and mazzard; Oak included black, chestnut and northern red.

^d Average density of stems by species groups within community may not add up to total due to rounding.

Table 40. Number of 2.0 m² sample plots, number of shrub and tree species^a and average^b density of shrub, tree and total species seedling-sized (stems ≤150 cm in height) stems (x 1000) by community at Valley Forge National Historical Park.

Community	Sample	Species		Stems		
	Plots	Shrubs	Trees	Shrub	Tree	Total ^c
	(-----Number-----)			(-----1000 per Hectare-----)		
Washington Chapel	6	7	8	42	40	82
River - Railroad	4	6	5	23	9	31
Railroad - River	4	5	0	26	0	26
Post Office	6	4	7	32	32	63
Basin 21	6	1	1	1	1	2
Wayne's Woods	6	3	3	26	5	31
Mount Misery	9	6	8	38	25	64
Mount Joy	8	6	3	24	6	29
Overall	49	16	15	27	16	43

^a Shrubs included blackberry-raspberry, blueberry, boxelder, dogwood spp., flowering dogwood, mapleleaf viburnum, mountain laurel, poison ivy, privet, rhododendron, rose spp., sassafras, smooth blackhaw, spicebush, wineberry and witch-hazel. Tree species included ash spp., bitternut hickory, black birch, black cherry, blackgum, black oak, chestnut oak, hickory spp., mazzard cherry, northern red oak, Norway maple, red maple, slippery elm, sugar maple and yellow-poplar.

^b Based on the number of plots for each community and all plots for overall.

^c Density of shrub and tree stems may not equal total due to rounding.

Table 41. List of herbaceous broadleaf, grass (and grass-like) and vine species that were recorded on at least one of the 49 - 2.0 m² sample plots at Valley Forge National Historical Park.

Broadleaf	Grass	Vine
Bedstraw	Bottlebrush grass	Bittersweet
Bellwort	An unknown	Grape spp.
Clearweed		Hog peanut
Enchanter's nightshade		Mile-a-minute
False Solomon's seal		Japanese honeysuckle
Garlic mustard		Virginia creeper
Hayscented fern		
Jack-in-the-pulpit		
Lady's thumb		
Striped pipsissewa		
An unknown		
Wild licorice		
White avens		
White snakeroot		
Yellow wood sorrel		

Table 42. Number of 2.0 m² sample plots and number^a of species by herbaceous group^b and community at Valley Forge National Historical Park.

Community	Sample Plots (No.)	Species Groups			Total
		Broadleaf	Grass	Vine	
		(-----Number of Species-----)			
Washington Chapel	6	6	1	4	11
River - Railroad	4	5	1	3	9
Railroad - River	4	5	1	1	8
Post Office	6	5	0	4	9
Basin 21	6	4	1	3	8
Wayne's Woods	6	6	0	4	10
Mount Misery	9	2	0	1	3
Mount Joy	8	8	1	4	13
Overall	49	16	2	5	22

^a Based on the number of plots for each community, and all plots for overall.

^b Broadleaves included bedstraw, bellwort, clearweed, enchanter's nightshade, false Solomon's seal, garlic mustard, hayscented fern, Jack-in-the-pulpit, lady's thumb, striped pipsissewa, unknown, wild licorice, white snakeroot, white avens and yellow wood sorrel. Grasses included bottlebrush grass and an unknown. Vines included bittersweet, grape, hog peanut, Japanese honeysuckle, mile-a-minute and Virginia creeper.

Table 43. Number of 2.0 m² sample plots and average^a coverage (%) by herbaceous group^b and community at Valley Forge National Historical Park.

Community	Sample Plots (No.)	Broadleaf (-----%)	Coverage		Total
			Grass	Vine	
Washington Chapel	6	17	<1	5	22
River - Railroad	4	25	39	3	67
Railroad - River	4	27	29	11	54
Post Office	6	21	0	7	28
Basin 21	6	14	58	4	75
Wayne's Woods	6	54	0	9	63
Mount Misery	9	4	0	<1	4
Mount Joy	8	15	24	7	46
Overall	49	20	18	5	43

^a Based on the number of plots for each community, and all plots for overall.

^b Broadleaves included bedstraw, bellwort, clearweed, enchanter's nightshade, false Solomon's seal, garlic mustard, hayscented fern, Jack-in-the-pulpit, lady's thumb, striped pipsissewa, unknown, wild licorice, white snakeroot, white avens and yellow wood sorrel. Grasses included bottlebrush grass and an unknown. Vines included bittersweet, grape, hog peanut, Japanese honeysuckle, mile-a-minute and Virginia creeper.

Table 44. Statistics from the 49 plot sample of number of shrub, tree and total species per 0.04 hectare plot and density of shrub, tree and total stems that were ≤ 10 cm in diameter at 1.3 m above ground, and sampling intensity to achieve 80, 90 and 95% probability by species group at Valley Forge National Historical Park.

	Species			Stems		
	Shrub	Tree	Total	Shrub	Tree	Total
Statistics from the Sample	(---Number/Plot---)			(-----Stems/Hectare-----)		
Average	2.9	3.0	5.8	1126	376	1501
Standard Deviation	1.5	1.7	2.0	1491	345	1439
Standard Error	0.2	0.2	0.3	213	49	206
Confidence Interval @ 80% ($\pm$)	0.3	0.3	0.4	279	65	269
Confidence Interval @ 90% ($\pm$)	0.4	0.4	0.5	359	83	346
Confidence Interval @ 95% ($\pm$)	0.4	0.5	0.6	430	100	415
Sampling Intensity	(-----Number of 0.04 Hectare Plots-----)					
Sample Number @ 80%	12	14	5	75	36	39
Sample Number @ 90%	78	95	33	496	239	260
Sample Number @ 95%	450	548	188	2866	1379	1500

Table 45. Statistics from the 49 plot sample of number of shrub, tree and total species per 0.04 hectare plot and density of shrub, tree and total stems that were > 10 cm in diameter at 1.3 m above ground, and sampling intensity to achieve 80, 90 and 95% probability by species group at Valley Forge National Historical Park.

	Species			Stems		
	Shrub	Tree	Total	Shrub	Tree	Total
Statistics from the Sample	(---Number/Plot---)			(---1000 Stems/Hectare---)		
Average	0.7	4.2	4.9	49	348	397
Standard Deviation	0.7	1.7	1.9	75	162	170
Standard Error	0.1	0.2	0.3	11	23	24
Confidence Interval @ 80% ($\pm$)	0.1	0.3	0.4	14	30	32
Confidence Interval @ 90% ($\pm$)	0.2	0.4	0.5	18	39	41
Confidence Interval @ 95% ($\pm$)	0.2	0.5	0.5	22	47	49
Sampling Intensity	(-----Number of 0.04 Hectare Plots-----)					
Sample Number @ 80%	45	7	6	101	9	8
Sample Number @ 90%	300	44	41	666	61	52
Sample Number @ 95%	1733	256	235	3844	351	299

Table 46. Statistics from the 49 plot sample of number of shrub, tree and total species per 2.0 m² plot and density of shrub, tree and total seedling-sized stems (x 1000) and sampling intensity to achieve 80, 90 and 95% probability by species group at Valley Forge National Historical Park.

	Species			Stems		
	Shrub	Tree	Total	Shrub	Tree	Total
Statistics from the Sample	(---Number?Plot--)			(1000 Stems/Hectare)		
Average	1.5	1.4	2.9	27	16	43
Standard Deviation	1.2	1.5	2.1	27	23	42
Standard Error	0.2	0.2	0.3	4	3	6
Confidence Interval @ 80% (±)	0.3	0.3	0.4	5	4	8
Confidence Interval @ 90% (±)	0.3	0.4	0.5	6	5	10
Confidence Interval @ 95% (±)	0.4	0.4	0.6	8	7	12
Sampling Intensity	(-----Number of 2.0 ² m Plots-----)					
Sample Number @ 80%	30	46	22	42	90	40
Sample Number @ 90%	192	302	142	279	590	267
Sample Number @ 95%	1107	1746	820	1613	3408	1540

Table 47. Statistics from the 49 plot sample of number of herbaceous species per 2.0 m² plot by herbaceous group, and sampling intensity to achieve 80, 90 and 95% probability by herbaceous group at Valley Forge National Historical Park.

	Species Groups			
	Broadleaf	Grass	Vine	Total
Statistics from the Sample	(-----Number of Species-----)			
Average	2.9	0.3	1.2	4.4
Standard Deviation	2.2	0.5	1.3	3.2
Standard Error	0.3	0.1	0.2	0.5
Confidence Interval @ 80% (±)	0.4	0.1	0.2	0.6
Confidence Interval @ 90% (±)	0.5	0.1	0.3	0.8
Confidence Interval @ 95% (±)	0.6	0.1	0.4	0.9
Sampling Intensity	(-----Number of 2.0 ² m Plots-----)			
Sample Number @ 80%	25	107	47	22
Sample Number @ 90%	162	705	308	146
Sample Number @ 95%	933	4074	1781	843

Table 48. Statistics from the 49 plot sample of coverage per 2.0 m² plot by herbaceous group and sampling intensity to achieve 80, 90 and 95% probability by herbaceous group at Valley Forge National Historical Park.

	Coverage			
	Broadleaf	Grass	Vine	Total
Statistics from the Sample	(------(%)-----)			
Average	20	18	5	43
Standard Deviation	21	33	8	39
Standard Error	3	5	1	6
Confidence Interval @ 80% (±)	4	6	2	7
Confidence Interval @ 90% (±)	5	8	2	9
Confidence Interval @ 95% (±)	6	10	2	11
Sampling Intensity	(-----Number of 2.0 ² m Plots-----)			
Sample Number @ 80%	48	152	93	35
Sample Number @ 90%	314	1003	615	232
Sample Number @ 95%	1816	5795	3551	1343

communities. From Tables 44 and 45, it appears that 75 or 101 - 0.04 hectare plots should produce acceptable results in inventorying the number of shrub, tree and total species as well as the density of shrub, tree and total species stems for the sapling- and tree-sized stems. An inventory from 75 plots would be expected to have 80 to 90% level of confidence in estimating all parameters, except the density of shrub stems that were >10 cm in diameter (Table 49). Increasing the number of plots sampled to 101 would be expected to achieve •80% level of confidence for all parameters (Table 49).

The level of confidence of estimating the seedling-sized and herbaceous plants was determined for the same number (75 and 101) and twice the number (150 and 202) of 0.04 hectare overstory plots (Table 49). Inventorying seedling-sized stems on 75 - 2.0 m² plots would be expected to have ≥80% level of confidence for all parameters except the density of tree and total. Increasing the number of plots to 101 would be expected to achieve ≥80% level of confidence in estimating the mean of all parameters. Inventorying the number of species and coverage of broadleaf, grass, vine and total herbaceous plants on 75 - 2.0 m² plots would be expected to have >80% level of confidence for 5 of the 8 parameters (Table 49). Increasing the number of plots to 101 would provide 80% level of confidence for all parameters except the number and coverage of grasses. To increase the level of confidence in all herbaceous parameters to ≥80%, at least 150 - 2.0 m² sample plots would need to be inventoried.

Numbers of plots and hours of effort required to collect, analyze and summarize overstory and understory data collected as part of a potential long-term forest monitoring program at the Valley Forge National Historical Park are presented in Table 50. The minimum total time to inventory the 75 - 0.04 hectare overstory plots and 75 - 2.0 m² understory plots in the forest communities was estimated to be 258.75 person-hours. Increasing the number of 0.04 hectare and 2.0 m² plots

Table 49. Probability of estimating average number of species and densities of stems for 1-to-10 cm and >10 cm in diameter at 1.3 m above ground (overstory) and seedling-sized stems (stems ≤ 150 cm in height) for shrub and tree species, and average numbers of herbaceous species and coverage values from selected numbers of sample plots in communities similar to those sampled in this study at Valley Forge National Historical Park.

Component	Number of Plots	Variable	Stems 1-to-10 cm			Stems >10 cm			
			Shrub	Tree	Total	Shrub	Tree	Total	
(-----Probability %-----)									
Overstory	75	No. Species	80	80	90	80	90	90	
		No. Stems	80	80	80	<80	90	90	
	101	No. Species	90	90	90	80	90	90	
		No. Stems	80	80	80	80	90	90	

Variable			Shrub	Tree	Total				
			(-----Probability %-----)						
Seedling- sized	75	No. Species	80	80	90				
		No. Stems	80	<80	<80				
	101	No. Species	80	80	80				
		No. Stems	80	80	80				
	150	No. Species	80	80	90				
		No. Stems	80	80	80				
	202	No. Species	90	80	90				
		No. Stems	80	80	80				

				Species Group					
	Variable			Broadleaf	Grass	Vine	Total		
				(-----Probability %-----)					
Herbaceous	75	No. Species	80	<80	80	80			
		Coverage	80	<80	<80	80			
	101	No. Species	80	<80	80	80			
		Coverage	80	<80	80	80			
	150	No. Species	80	80	80	90			
		Coverage	80	80	80	80			
	202	No. Species	90	80	80	80			
		Coverage	80	80	80	80			

Table 50. Numbers of plots and hours of effort required to collect, analysis and summarize overstory and understory data collected as part of a potential long-term forest monitoring program at the Valley Forge National Historical Park.

Overstory		Seedling-sized		Herbaceous		Total Hours
Number of Plots	Hours ^a	Number of Plots	Hours ^b	Number of Plots	Hours ^c	
75	120.00	75	75.00	75	63.75	258.75
75	120.00	150	150.00	150	127.50	397.50
101	161.60	101	101.00	101	85.85	348.45
101	161.60	202	202.00	202	171.71	535.30

^a It was estimated to take 1.6 person-hours per plot to locate, inventory the sapling-sized and tree-sized shrub and tree stems on a 0.04 ha plot, enter the data into a computer file and summarize the information.

^b It was estimated to take 1.0 person-hours per plot to locate, inventory the seedling-sized shrub and tree stems on a 2.0 m² plot, enter the data into a computer file and summarize the information.

^c It was estimated to take 0.85 person-hours per plot to locate, inventory the herbaceous plants on a 2.0 m² plot, enter the data into a computer file and summarize the information. This assumes that the plot would be the same as for the seedling-sized inventory.

to 101, each, would increase the time required to 348.45 person-hours. These 101 plots would be expected to achieve ≥80% level of confidence in estimating the mean of all overstory and understory parameters, except number of grass species and grass coverage. A third reasonable alternative would be to inventory the overstory with 75 - 0.04 hectare plots and inventory the understory with 150 - 2.0 m² plots. This alternative would require 397.50 person-hours of effort. It would result in estimating all parameters at ≥80% level of confidence, except the density of shrub species stems per hectare in the >10 cm diameter class. We believe the 101 sample points with one 0.04 hectare plot for the sapling-sized and tree-sized parameters and one 2.0 m² plot for the seedling-sized and herbaceous plant parameters would provide the best balance of precision and effort. This inventory plan, conducted in forest communities similar to those in this study data set, should provide Valley Forge National Historical Park with an adequate database for establishing a comprehensive long-term monitoring program.

Numbers of sample plots to inventory the number of shrub, tree and total species per plot and density of shrub, tree and total, by size class and community, to achieve 80% probability by species group are presented in Appendix IV. These values were presented to provide an estimate on the community specific sample inventory requirements. These values should be viewed only in a general sense because the procedures used in this study were to provide site-wide information and not community specific information.

DISCUSSION

Sapling and Tree-sized Stems

Valley Forge National Historical Park had greater numbers of sapling-sized and tree-sized shrub and tree species than Hopewell Furnace National Historic Site. There were 18 and 24 sapling-sized shrub and tree species, respectively, at Valley Forge National Historical Park, whereas Hopewell Furnace National Historic Site had 16 sapling-sized shrub species and 18 sapling-sized tree species. The numbers of tree-sized shrub and tree species were 6 and 30, respectively, at Valley Forge National Historical Park, compared to 4 and 19 species at Hopewell Furnace National Historic Site.

Overall, the average density of sapling-sized stems was greater at Valley Forge National Historical Park (1502 stems/ha) than at Hopewell Furnace National Historic Site (800 stems/ha). Conversely, the total average density of tree-sized stems was greater at Hopewell Furnace National Historic Site than at Valley Forge National Historical Park (435 and 397 stems/ha, respectively). Storm et al. (1994) reported average densities of 1,460 and 629 sapling-sized stems/ha for two forest stands at Hopewell Furnace National Historic Site. The average densities of tree-sized stems were 387 and 420 stems/ha. Russell (1987) found averages of 426 sapling-sized stems/ha and 518 tree-sized stems/ha at Hopewell Furnace National Historic Site. Valley Forge National Historical Park had greater average densities of sapling-sized shrub stems (1126 stems/ha) and tree-sized shrub stems (51 stems/ha) than Hopewell Furnace National Historic Site (352 sapling-sized and 11 tree-sized shrub stems/ha, respectively). The most abundant sapling-sized shrubs at both Valley Forge National Historical Park and Hopewell Furnace National Historic Site were spicebush (averages of 278 and 91 stems/ha, respectively) and viburnum (averages of 231 and 92 stems/ha, respectively). The most abundant tree-sized shrubs at Valley Forge National Historical Park were dogwood and spicebush, with overall average densities of 18 and 14 stems/ha, respectively. At Hopewell Furnace National Historic Site, the dominant tree-sized shrubs were sassafras (5 stems/ha) and ironwood (4 stems/ha). Hopewell Furnace National Historic Site had greater average densities of sapling-sized tree stems (448 stems/ha) and tree-sized tree stems (424 stems/ha) than Valley Forge National Historical Park (376 and 349 sapling-sized and tree-sized tree stems/ha, respectively). At Hopewell Furnace National Historic Site, the most abundant sapling-sized trees were birch (112 stems/ha) and maple (82 stems/ha). The most abundant sapling-sized trees at Valley Forge National Historical Park were maple and blackgum (114 and 83 stems/ha, respectively). The dominant tree-sized trees were maple and oak (both 114 stems/ha) at Hopewell Furnace National Historic Site and yellow poplar (79 stems/ha) and oak (64 stems/ha) at Valley Forge National Historical Park.

Seedling-sized Stems

For seedling-sized stems, Valley Forge National Historical Park had a greater number of total shrub species (16 species) than Hopewell Furnace National Historic Site (15 species). Both Valley Forge National Historical Park and Hopewell Furnace National Historic Site had 15 total tree species.

Hopewell Furnace National Historic Site had greater average densities of seedling-sized shrub stems (49,000 stems/ha), tree stems (26,000 stems/ha) and total stems (74,000 stems/ha) than Valley Forge National Historical Park (27,000, 17,000, and 43,000 shrub, tree, and total stems/ha, respectively). Storm et al. (1994) reported averages of 14,000 and 13,500 seedling-sized shrub stems/ha for the Chestnut Hill and Mount Pleasure areas at Hopewell Furnace National Historic Site. The average densities of seedling-sized tree stems for the two forested areas were 29,750 and 12,417 stems/ha. At Hopewell Furnace National Historic Site, the most abundant seedling-sized shrubs were other shrubs, including blackberry and raspberry, blueberry, great rhododendron, and greenbriar (30,000 stems/ha) and spicebush (7,000 stems/ha). At Valley Forge National Historical Park, the most abundant seedling-sized shrubs were spicebush (7,000 stems/ha) and blackberry and viburnum (both 5,000 stems/ha). The dominant seedling-sized trees at Hopewell Furnace National Historic Site were maple and oak (9,000 and 7,000 stems/ha, respectively), while at Valley Forge National Historical Park, ash (5,000 stems/ha) and cherry and oak (both 3,000 stems/ha) were most abundant.

Herbaceous

Hopewell Furnace National Historic Site had greater numbers of broadleaf and vine species (18 and 6 species, respectively) than Valley Forge National Historical Park (16 and 5 broadleaf and vine species, respectively). There were 2 grass species at both Hopewell Furnace National Historic Site and Valley Forge National Historical Park. Conversely, percent coverage was greater at Valley Forge National Historical Park for broadleaves (20%), vines (5%), and total (43%) than at Hopewell Furnace National Historic Site (12, 2, and 32% broadleaf, vine, and total coverage, respectively). Grass coverage was 18% at both Hopewell Furnace National Historic Site and Valley Forge National Historical Park.

Long-term Monitoring

The long-term monitoring program being considered for Hopewell Furnace National Historic Site and Valley Forge National Historical Park is for the purpose of providing a quantitative estimate of major temporal changes that may be occurring in the density and species composition in the overstory and understory plants. Data collection on a unit area by individual species will provide the opportunity to develop most of the commonly used metrics of plant communities. The number of plots needed for the monitoring program were determined for the coarse metrics of numbers of species, coverage by herbaceous groups and density of seedling-, sapling- and tree-sized shrub and tree species stems. More detailed metrics, such as number of stems by specific species or densities of stems by 5 cm diameter classes, could require >1000 sample plots for each location. In addition, there may be an interest in collecting community-specific information. Numbers of sample plots needed to achieve 80% probability of estimating the number of species and number of stems per hectare in the individual communities by size class and species groups are presented in Appendices III and IV. These data provide general information on potential sample requirements for the individual communities at Hopewell Furnace National Historic Site and Valley Forge National Historical Park, respectively. Direct use of these data is not recommended because the sampling procedures used in this report were designed to provide park wide estimates and not individual community values. However, these

data can be used as a preliminary inventory estimate for developing sampling procedures to determine community specific sampling requirements.

The long-term monitoring program should not be viewed as a replacement for other issue specific studies, such as measuring the impact of white-tailed deer or tall grass monitoring. These studies have developed specific methodologies appropriate for the individual studies' objectives.

In addition to inventorying the plants in the overstory and the understory, we believe that it would be useful to record selected non-vegetation attributes of soil and topography at the sample plots. Soil attributes of amount of surface area covered by surface rocks, litter thickness and soil series name should be recorded. Topographic attributes to be recorded would be aspect, elevation and slope.

Number of communities to be inventoried as a basis for Hopewell Furnace National Historic Site or Valley Forge National Historical Park wide monitoring programs will need to be determined. We inventoried five communities at Hopewell Furnace National Historic Site and eight areas at Valley Forge National Historical Park because these were the ones that the Park Service personnel were interested in including in their monitoring program. Regardless of which communities are included, we suggest an aerial proportional assignment of number of plots per community, with a minimum of six plots per community. Either square or circular plots can be selected. Circular plots require the lowest amount of field marking, are the simplest to install and maintain and have the lowest amount of plot edge. All shrub and tree species stems >10 cm in diameter should be inscribed with a horizontal mark in the bark at 1.35 m above ground. The scribe mark should face towards the plot center. Plots for monitoring the herbaceous and seedling-sized plants should be located at least 2 m from the overstory plot center. All plots need to be marked in the field with a reference number on a metal tag attached to a long-lasting stake. Distance and azimuth of a permanent landmark and the Universal Traverse Meccator coordinates for each plot should be recorded to permit linkage with the geographic information system and future relocation.

We believe that a monitoring plan in forest communities similar to those in this study data set should provide Hopewell Furnace National Historic Site and Valley Forge National Historical Park with an adequate database for establishing a comprehensive long-term monitoring program. At Hopewell Furnace National Historic Site, 70 sample points with 1 - 0.04 hectare plot for the sapling-sized and tree-sized parameters and 2 - 2.0 m² plots for the seedling-sized and herbaceous plant parameters would provide the best balance of precision and effort. At Valley Forge National Historical Park, we believe the 101 sample points with 1 - 0.04 hectare plot for the sapling-sized and tree-sized parameters and 1 - 2.0 m² plot for the seedling-sized and herbaceous plant parameters would provide the best balance of precision and effort. There is a note of caution if it is decided to use twice as many understory plots as overstory plots. Sample design for this report used one seedling-sized and herbaceous plot per sample point. Appropriate application of the results from this study to inventory 140 - 2.0 m² plots for the understory and 70 - 0.04 ha plots for the overstory will require randomly locating 70 additional sample points. Only seedling-sized and herbaceous plants would be recorded at the additional 70 sample points. In reality, we do not believe there would be any statistical difference in sampling the understory strata from 140 separate sample points or from 2 - 2 m² plots per 70 sample points.

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APPENDICES

Appendix I. Common and scientific names of herbaceous (broadleaves and grasses), shrub, tree and vine species identified during the study and presented in this report for Hopewell Furnace National Historic Site.

Herbaceous species include annual, biennial, or perennial plants whose exposed parts die down at the end of growing season and included broadleaves (B) and grasses or grass-like (G); a shrub (S) is defined as having a persistent woody stem, may have either single or multiple stems and are ≤ 10 m in height; a tree (T) is defined as having a persistent woody stem, usually a single stem and capable of achieving heights >10 m; and a vine (V) is defined as having a persistent woody stem that is capable of climbing. All species in this appendix are listed by family, scientific name, and common name where known. Taxonomy follows that of Pool (1978) and Rhoads and Klein (1993).

Aceraceae	<i>Acer platanoides</i> L. - Norway maple (T) <i>Acer rubrum</i> L. - red maple (T)
Berberidaceae	<i>Berberis thunbergii</i> DC. - Japanese barberry (S) <i>Thalictrum thalictroides</i> (L.) Eames & B. Boivin - rue anemone (B)
Betulaceae	<i>Betula alleghaniensis</i> Britt. - yellow birch (T) <i>Betula lenta</i> L. - black birch (T) <i>Carpinus caroliniana</i> Walter - ironwood (S)
Caprifoliaceae	<i>Lonicera tatarica</i> L. - Tatarian honeysuckle (S) <i>Viburnum acerifolium</i> L. - maple-leaved viburnum (S) <i>Viburnum dentatum</i> L. - arrowwood (S) <i>Viburnum prunifolium</i> L. - black-haw (S)
Cornaceae	<i>Cornus florida</i> L. - flowering dogwood (S)
Ericaceae	<i>Kalmia latifolia</i> L. - mountain laurel (S) <i>Rhododendron maximum</i> L. - great rhododendron (S) <i>Vaccinium</i> spp. - blueberry species (S)
Fagaceae	<i>Castanea dentata</i> (Marshall) Borkh. - American chestnut (S) <i>Fagus grandifolia</i> Ehrhart - American beech (T) <i>Quercus alba</i> L. - white oak (T) <i>Quercus coccinea</i> Muenchh. - scarlet oak (T) <i>Quercus prinus</i> L. - chestnut oak (T) <i>Quercus rubra</i> L. - northern red oak (T) <i>Quercus velutina</i> Lam. - black oak (T)

Hamamelidaceae	<i>Hamamelis virginiana</i> L. - witch-hazel (S)
Juglandaceae	<i>Carya glabra</i> (P. Mill.) Sweet - pignut hickory (T) <i>Carya ovata</i> (P. Mill.) K. Koch - shagbark hickory (T) <i>Carya tomentosa</i> (Lam. ex Poir.) Nutt. - mockernut hickory (T)
Lauraceae	<i>Lindera benzoin</i> (L.) Blume - spicebush (S) <i>Sassafras albidum</i> (Nutt.) Nees - sassafras (S)
Lemnaceae	<i>Symplocarpus foetidus</i> (L.) Salisb. ex Nutt. - skunk cabbage (B)
Magnoliaceae	<i>Liriodendron tulipifera</i> L. - yellow poplar (T)
Nyssaceae	<i>Nyssa sylvatica</i> Marshall - black-gum (T)
Oleaceae	<i>Fraxinus</i> spp. - ash spp. (T)
Rosaceae	<i>Agrimonia rostellata</i> Wallr. - woodland agrimony (B) <i>Amelanchier arborea</i> (Michx. f.) Fern. - serviceberry (S) <i>Crataegus</i> spp. - hawthorn species (S) <i>Fragaria</i> spp. - strawberry species (B) <i>Prunus avium</i> (L.) L. - sweet cherry (T) <i>Prunus serotina</i> Ehrh. - wild black cherry (T) <i>Rosa</i> spp. - mainly multiflora rose (S) <i>Rubus</i> spp. - blackberry, dewberry or black raspberry (S)
Rubiaceae	<i>Mitchella repens</i> L. - partridgeberry (B)
Salicaceae	<i>Populus grandidentata</i> Michx. - bigtooth aspen (T)
Smilacaceae	<i>Smilax rotundifolia</i> L. - greenbriar (S)
Ulmaceae	<i>Ulmus americana</i> L. - American elm (T) <i>Ulmus rubra</i> Muhl. - slippery elm (T)
Violaceae	<i>Viola</i> spp. - violet species (B)

Appendix II. Common and scientific names of herbaceous (broadleaves and grasses), shrub, tree and vine species identified during the study and presented in this report for Valley Forge National Historical Park.

Herbaceous species include annual, biennial, or perennial plants whose exposed parts die down at the end of growing season and included broadleaves (B) and grasses or grass-like (G); a shrub (S) is defined as having a persistent woody stem, may have either single or multiple stems and are <10 m in height; a tree (T) is defined as having a persistent woody stem, usually a single stem and capable of achieving heights >10 m; and a vine (V) is defined as having a persistent woody stem that is capable of climbing. All species in this appendix are listed by family, scientific name, and common name where known. Taxonomy follows that of Pool (1978) and Rhoads and Klein (1993).

Aceraceae	<i>Acer negundo</i> L. - boxelder (S) <i>Acer platanoides</i> L. - Norway maple (T) <i>Acer rubrum</i> L. - red maple (T) <i>Acer saccharinum</i> L. - silver maple (T) <i>Acer saccharum</i> Marshall - sugar maple (T)
Anacardiaceae	<i>Toxicodendron radicans</i> (L.) Kuntze - poison-ivy (V)
Araceae	<i>Arisaema triphyllum</i> (L.) Schott - jack-in-the-pulpit (B)
Asteraceae	<i>Eupatorium rugosum</i> Houtt - white-snakeroot (B)
Betulaceae	<i>Betula lenta</i> L. - black birch (T) <i>Betula nigra</i> L. - river birch (T) <i>Carpinus caroliniana</i> Walter - ironwood (S)
Bignoniaceae	<i>Catalpa speciosa</i> (Warder ex Barney) Warder ex Engelm. - northern catalpa (T)
Brassicaceae	<i>Alliaria petiolata</i> (Bieb.) Cavara & Grande - garlic-mustard (B)
Caprifoliaceae	<i>Lonicera japonica</i> Thunb. - Japanese honeysuckle (V) <i>Lonicera tatarica</i> L. - Tatarian honeysuckle (S) <i>Viburnum acerifolium</i> L. - maple-leaved viburnum (S) <i>Viburnum prunifolium</i> L. - black-haw (S)
Celastraceae	<i>Celastrus scandens</i> L. - bittersweet (V)
Cornaceae	<i>Cornus florida</i> L. - flowering dogwood (S) <i>Cornus</i> spp. - dogwood species (S)
Ericaceae	<i>Kalmia latifolia</i> L. - mountain laurel (S)

	<i>Rhododendron maximum</i> L. - great rhododendron (S)
	<i>Vaccinium</i> spp. - blueberry species (S)
Fabaceae	<i>Amphicarpaea bracteata</i> (L.) Fern. - hog-peanut (V)
	<i>Robinia pseudoacacia</i> L. - black locust (T)
Fagaceae	<i>Fagus grandifolia</i> Ehrhart - American beech (T)
	<i>Quercus alba</i> L. - white oak (T)
	<i>Quercus coccinea</i> Muenchh. - scarlet oak (T)
	<i>Quercus prinus</i> L. - chestnut oak (T)
	<i>Quercus palustris</i> Muenchh. - pin oak (T)
	<i>Quercus rubra</i> L. - northern red oak (T)
	<i>Quercus velutina</i> Lam. - black oak (T)
Hamamelidaceae	<i>Hamamelis virginiana</i> L. - witch-hazel (S)
Hymenophyllaceae	<i>Dennstaedtia punctilobula</i> (Michx.) T. Moore - hayscented fern (B)
Juglandaceae	<i>Carya cordiformis</i> (Wangenheim) K. Koch - bitternut hickory (T)
	<i>Carya ovata</i> (P. Mill.) K. Koch - shagbark hickory (T)
	<i>Carya</i> spp. - hickory (T)
	<i>Carya tomentosa</i> (Lam. ex Poir.) Nutt. - mockernut hickory (T)
	<i>Juglans cinerea</i> L. - butternut (T)
	<i>Juglans nigra</i> L. - black walnut (T)
Lauraceae	<i>Lindera benzoin</i> (L.) Blume - spicebush (S)
	<i>Sassafras albidum</i> (Nutt.) Nees - sassafras (S)
Leguminosae	<i>Cercis canadensis</i> L. - redbud (S)
Liliaceae	<i>Smilacina racemosa</i> (L.) Desf. - false solomon's-seal (B)
	<i>Uvularia perfoliata</i> L. - bellwort (B)
Magnoliaceae	<i>Liriodendron tulipifera</i> L. - yellow poplar (T)
	<i>Magnolia</i> spp. - magnolia species (T)
Nyssaceae	<i>Nyssa sylvatica</i> Marshall - black-gum (T)
Oleaceae	<i>Fraxinus</i> spp. - ash spp. (T)
	<i>Ligustrum obtusifolium</i> Sieb. & Zucc. - privet (S)
Onagraceae	<i>Circaea lutetiana</i> L. - enchanter's-nightshade (B)
Oxalidaceae	<i>Oxalis stricta</i> L. - yellow wood-sorrel (B)
Pinaceae	<i>Pinus strobus</i> L. - eastern white pine (T)

	<i>Tsuga canadensis</i> (L.) Carrière - eastern hemlock (T)
Poaceae	<i>Elymus hystrix</i> L. - bottlebrush grass (G)
Polygonaceae	<i>Polygonum perfoliatum</i> L. - mile-a-minute (B) <i>Polygonum persicaria</i> L. - lady's-thumb (B)
Pyrolaceae	<i>Chimaphila maculata</i> (L.) Pursh - striped pipsissewa (B)
Rosaceae	<i>Crataegus</i> spp. - hawthorn species (S) <i>Geum canadense</i> Jacq. - white avens (B) <i>Malus</i> spp. - apple species (S) <i>Prunus avium</i> (L.) L. - sweet cherry (T) <i>Prunus serotina</i> Ehrh. - wild black cherry (T) <i>Rosa</i> spp. - mainly multiflora rose (S) <i>Rubus phoenicolasius</i> Maxim. - wineberry (S) <i>Rubus</i> spp. - blackberry, dewberry or black raspberry (S)
Rubiaceae	<i>Galium circaezans</i> Michx. - wild licorice (B) <i>Galium concinnum</i> Torr. & A. Gray - bedstraw (B)
Salicaceae	<i>Populus deltoides</i> Marshall - eastern cottonwood (T) <i>Salix</i> spp. - willow species (T)
Simaroubaceae	<i>Ailanthus altissima</i> (Miller) Swingle - tree-of-heaven (T)
Staphyleaceae	<i>Staphylea trifolia</i> L. - bladdernut (S)
Ulmaceae	<i>Celtis</i> spp. - hackberry (T) <i>Ulmus americana</i> L. - American elm (T) <i>Ulmus rubra</i> Muhl. - slippery elm (T)
Urticaceae	<i>Pilea pumila</i> (L.) A. Gray. - clearweed (B)
Vitaceae	<i>Parthenocissus quinquefolia</i> (L.) Planch. - Virginia-creeper (V) <i>Vitis</i> spp. - grape species (V)

Appendix III. Numbers of sample plots needed to achieve 80% probability of estimating the number of species and number of stems per hectare in the individual communities by size class and species groups at Hopewell Furnace National Historic Site.

Community	Size Class								
	Seedlings			Saplings			Tree		
	Shrub	Tree	Total	Shrub	Tree	Total	Shrub	Tree	Total
Number of Species	(-----Number of Sample Plots per Community-----)								
Mixed oak - black birch	12	21	9	15	10	7	a	3	4
Tulip poplar - oak	6	15	4	19	3	6	a	2	2
Tulip poplar - red maple	38	4	7	16	15	2	a	9	9
Mixed oak	12	18	4	40	4	7	72	1	1
Red maple	15	2	4	11	13	7	a	11	15
Number of Stems	(-----Number of Sample Plots per Community-----)								
Mixed oak - black birch	15	25	10	22	22	16	a	1	1
Tulip poplar - oak	18	71	32	56	15	25	a	2	2
Tulip poplar - red maple	46	15	5	49	17	16	a	1	1
Mixed oak	11	99	27	57	12	33	a	3	2
Red maple	27	15	9	25	a	21	a	6	5

a Too few species or stems present to determine.

Appendix IV. Numbers of sample plots needed to achieve 80% probability of estimating the number of species and number of stems per hectare in the individual communities by size class and species groups at the Valley Forge National Historical Park.

Community	Size Class								
	Seedlings			Saplings			Tree		
	Shrub	Tree	Total	Shrub	Tree	Total	Shrub	Tree	Total
Number of Species	(-----Number of Sample Plots per Community-----)								
Washington Chapel	9	38	9	13	24	1	18	12	12
River – Railroad	7	13	2	3	1	3	70	1	3
Railroad – River	a	25	25	5	1	1	70	3	6
Post Office	16	13	11	9	5	6	35	5	3
Basin 21	a	a	a	29	10	4	64	1	3
Wayne's Woods	60	13	5	1	51	1	a	34	31
Mount Misery	15	16	4	22	9	9	60	1	1
Mount Joy	38	43	33	8	6	5	38	4	3
Number of Stems	(-----Number of Sample Plots per Community-----)								
Washington Chapel	17	35	20	23	52	14	56	5	3
River – Railroad	57	6	6	24	10	14	70	4	6
Railroad – River	a	33	33	7	41	10	58	8	10
Post Office	23	17	12	15	15	11	30	3	1
Basin 21	a	a	a	25	15	10	64	2	2
Wayne's Woods	69	13	3	10	56	10	a	8	12
Mount Misery	73	35	29	44	12	19	70	5	5
Mount Joy	43	80	62	63	21	25	71	6	6

a Too few species or stems present to determine.