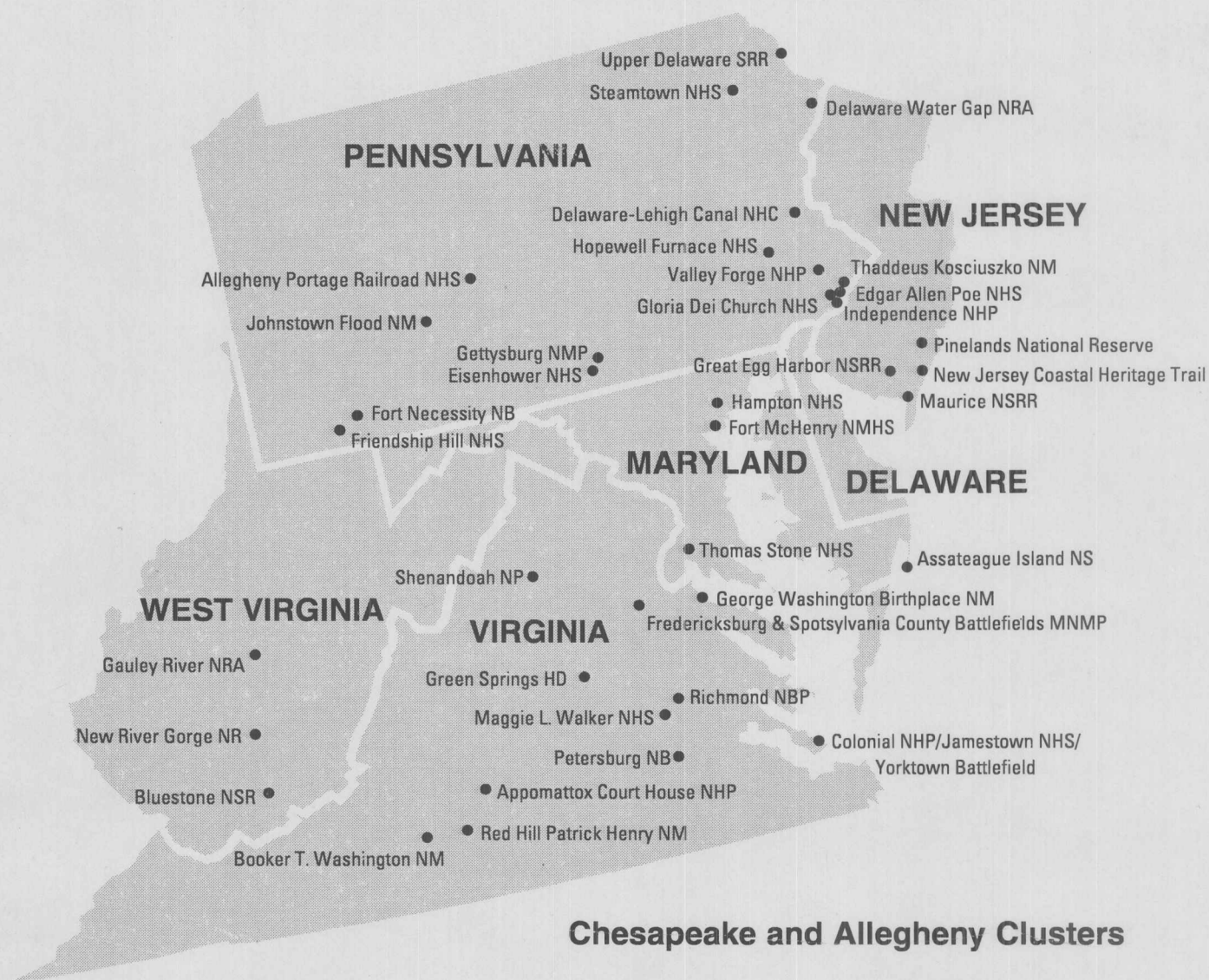


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SUMMARY

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.

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

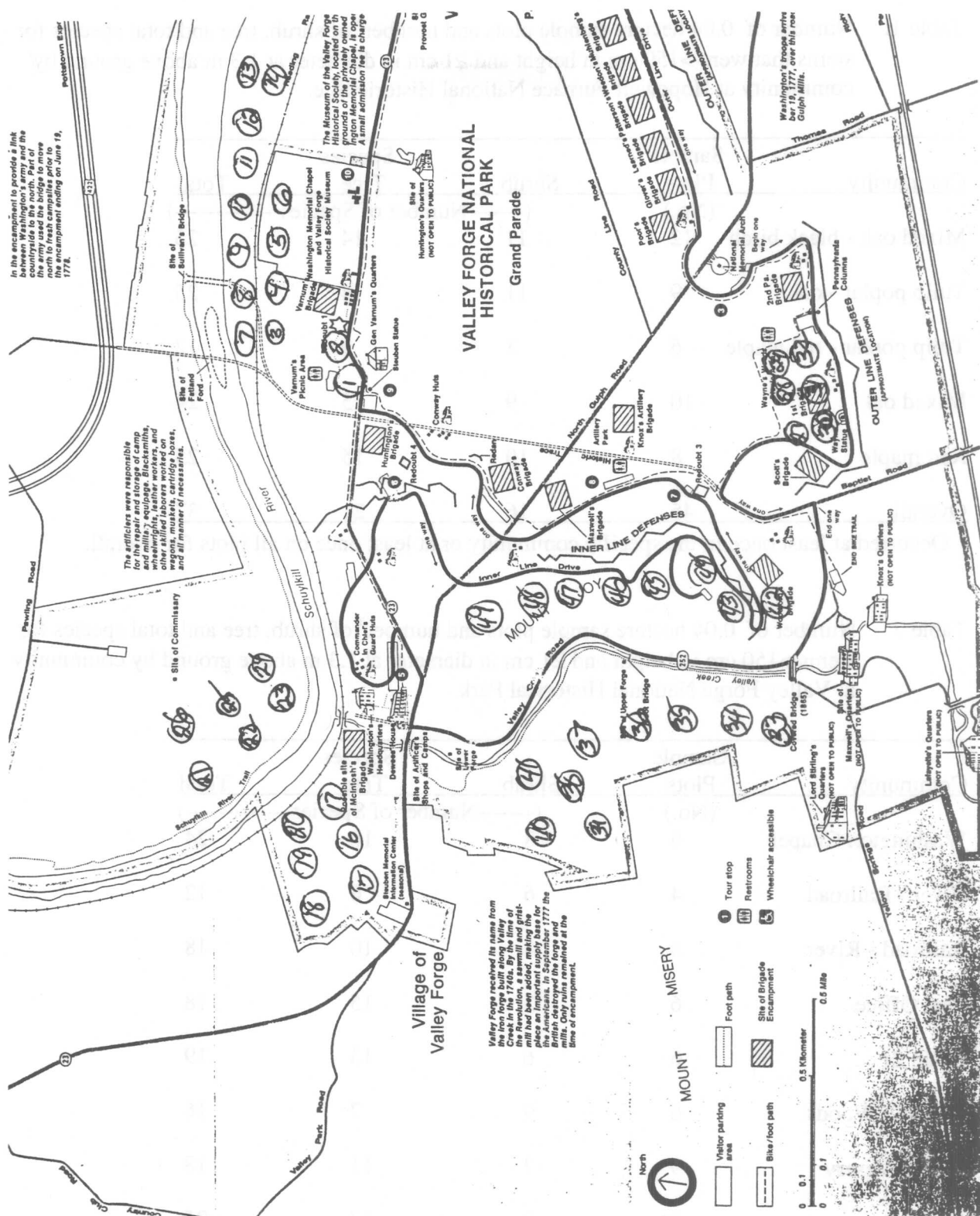


Figure 2. Public use map for Valley Forge National Historical Park with approximate locations of the 49 - 0.04 hectare sample plots.

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 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	115	17	2		2	2									
-black birch															
Tulip poplar	539	42	3												
-oak															
Tulip poplar	267														
-red maple															
Mixed oak	130	43	15												
Red maple	625	91	25												
Overall	314	38	9		1	1									
Tree															
Mixed oak	635	246	148	56	35	33	27	27	10	23	17	2	13	2	8
-black birch															
Tulip poplar	192	147	64	39	53	25	56	25	28	28	19	6		3	6
-oak															
Tulip poplar	21	96	100	71	75	42	75	71	63				4		
-red maple															
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

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 6. Number of 0.04 hectare sample plots^a, tree species^b and average^c 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	Plots	Species	Maple	Birch	Hickory	Ash	Yellow-Black-				Oak	Other	Total ^d
							poplar	gum	Cherry	Tree			
							Stems per Hectare						
Mixed oak	12	9	108	371	6	0	292	56	6	4	38	881	
-black birch													
Tulip poplar	9	10	58	56	3	11	3	136	17	6	50	339	
-oak													
Tulip poplar	6	6	71	8	0	13	8	0	4	0	13	117	
-red maple													
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 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 (--Number--)	Species	Maple	Birch	Hickory	Ash	Yellow- poplar	Black- gum	Cherry	Oak	Other Tree	Total ^d
Stems per Hectare-----)												
Mixed oak	12	13	69	117	10	0	50	33	0	94	29	402
-black birch												
Tulip poplar	9	12	72	86	6	3	36	50	0	81	14	350
-oak												
Tulip poplar	6	6	75	0	0	13	379	13	21	0	0	500
-red maple												
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 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 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

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 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		Total ^c
	Plots	Shrubs	Trees	Shrub	Tree	
	(-----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 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	Species Group			Total
	Plots	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 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

>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 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.

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.

Shrub Species	Tree Species
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.
	Yellow-poplar

Table 28. Continued.

Species Group	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
Community	1217	229	75	42	21	29	33	4	29	13	8	25	4	4	13
Total ^b	(-----Stems per Hectare-----)														
Washington Chapel	307	269	81	81	50	31	31	31	13	31	13				6
River - Railroad	219	388	219	138	31	56	25	25	19	13		6	6		
Railroad - River	708	312	96	33	33	21	25	50	25	29	8	4	4	8	
Post Office	246	409	242	138	104	83	29	13	8	13			4		
Basin 21	4041	92	37	54		8	17	17	17	13	21	25	17	25	17
Wayne's Woods	1222	575	161	86	31	11	53	33	22	14	6	14	8		
Mount Misery	640	500	128	44	19	28	25	22	6	9	9	19	9	6	9
Mount Joy	1133	369	130	73	35	32	32	25	17	16	8	13	7	6	6
Overall															

^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.

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 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 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 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 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 1-50	Height Class 51-150	Height Class 1-50	Height Class 51-150	Height Class 1-50	Height Class 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

(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 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		Total ^c
	Plots	Shrubs	Trees	Shrub	Tree	
	(-----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 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	Species Groups			Total
	Plots (No.)	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 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 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	(-----Number of 2.0 ² m Plots-----)			
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 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.

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

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

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

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

a Too few species or stems present to determine.

