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Desired Condition of Grasslands and Meadows in Valley Forge National Historical Park

Natural Resource Technical Report NPS/NER/VAFO/NRTR—2012/632

ON THE COVER

Grassland in Valley Forge National Historical Park
Photograph by Bill Moses

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Abstract

The grasslands and meadows of Valley Forge National Historical Park cover 541 ha (1,340 acres), nearly 44% of the total park area. This is one of the largest areas of permanently maintained but uncultivated, upland, herbaceous vegetation in the Mid-Atlantic Region. Uncultivated grasslands and meadows are increasingly gaining recognition as vital habitats for many native plants and animals at the same time as they are becoming scarcer and the species that depend on them are undergoing alarmingly rapid declines. However, present conditions in the fields are ecologically marginal; they are dominated by nonnative, invasive plant species, which are of low value as food for insects and thus support low biomass, low diversity, low numbers, and low population viability of wildlife species throughout the food web, relative to grasslands and meadows dominated by native plants. The challenges of specifying a desired condition for these lands include staying true to the main historical mission of the park and accurately describing historical species assemblages that until now have been neglected as a subject of research in historical ecology and community classification.

Fully authentic historical reconstruction of the fields for the historical period commemorated by the park would require a large-scale farming operation, which in practical terms would entail soil tilling and the application of manure or other fertilizer and perhaps herbicides and pesticides, practices that would violate the National Park Service's commitment to conserving soil, water quality, habitat for native wildlife, and the integrity of native plant communities. However, fallow fields dominated by native species are historically authentic for the commemorated period given the farming practices of that era. Undertaking native grassland and meadow reclamation in the fields of Valley Forge National Historical Park will, in effect, boost the proportion of native-species-dominated fallow fields from the estimated eighteenth-century average of 17%–33% to near 100%. In so doing, the National Park Service will:

- create a regionally significant core area of high-quality wildlife habitat of a type that has undergone severe decline
- strengthen the population viability of nearly 40 imperiled or declining plant and animal species recently confirmed as present in the park's grasslands and meadows and potentially, through translocation of local genotypes, more than 50 other species of special concern recorded historically at Valley Forge or present in remnant populations nearby
- provide opportunities to safeguard wildlife species imperiled by climate change, habitat fragmentation, habitat loss or other causes through "assisted migration" and establishment of new populations
- enhance ecosystem resilience to the likely effects of climate change, including higher temperatures, greater variability in precipitation, and longer droughts
- provide the best available deterrence against soil erosion (maintaining the integrity of soil-situated archaeological remains and protecting stream- and groundwater quality in the process)
- lessen the park's impact on neighboring ecosystems, as a source of invasive plant species' seeds
- reduce the "carbon footprint" of park operations

In addition, converting the fields to native grassland and meadow vegetation has the potential to significantly enhance other park values, including historical authenticity, interpretive opportunities, and aesthetics, compared with present conditions.

1 Introduction

1.1 Purpose

The purpose of the analysis presented in this document is to develop specific, measurable desired condition objectives for grasslands and meadows at Valley Forge National Historical Park (VAFO). Desired conditions are measurable, quantitative descriptions of the states of various resources that will indicate success in achieving management goals, including the restoration and maintenance of ecological integrity. They include a range of target values for various indicators of resource condition and for key factors in maintaining resources within those ranges. Identifying desired conditions begins with our best understanding of the state of the environment before European settlement and takes into account constraints imposed by subsequent changes, such as species extinction and extirpation, habitat fragmentation and isolation, soil modification, introduction of nonnative organisms, and shifting climate.

Grasslands and meadows have unique significance for biological diversity conservation. Worldwide, the ratio of area destroyed to area protected is ten to one for temperate grassland and shrubland, five times higher than for the tropical rainforest (Hoekstra et al. 2004). The situation is even worse in eastern North America, where native grasslands have been under extreme pressure for more than 300 years and most were converted long ago to agricultural, residential, commercial and other uses. Half of Pennsylvania's grassland bird species are classified as endangered, threatened or candidates at risk and nearly all have undergone serious declines in recent decades. Of the Lepidoptera species classified as endangered, threatened or rare in the state, at least 74% of butterflies and 38% of moths are known to depend in part or wholly on grassland and meadow habitats (Latham and Thorne 2007). Counterintuitively, in regard to carbon dioxide cycling and global climate change, temperate zone grasslands sequester as much organic carbon per unit of land area as forests, substantially more than croplands and other agroecosystems (Gibson 2009). More details on the conservation significance of grassland and meadow ecosystems are given in Appendix A (p. 129).

Desired condition analysis is an important component of the science-based approach to ecosystem management promoted by the National Park Service, U.S. Forest Service, and other conservation agencies and organizations (Eckert 2009). The process ties together adaptive resource management, ecological restoration, master planning, ecosystem monitoring and outcomes assessment. A desired condition analysis is a qualitative and quantitative description of ecosystem attributes that are expected to be present at some point in time as an outcome of deliberate management policies, strategies and practices. An ecosystem attribute is defined as any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. A desired condition is not an attempt to return to the past, but takes into account both what is known about pre-degradation conditions and important influences that have been added or taken away since European settlement and are beyond managers' ability to control.

The grasslands and meadows of VAFO comprise one of the largest areas of permanently maintained but uncultivated, upland, herbaceous vegetation in the Mid-Atlantic Region. The park encompasses 1,293 ha (3,195 acres)* altogether and grasslands and meadows cover 541 ha (1,340 acres) in large expanses and scattered fragments,

* Excludes 102 ha (253 acres) of privately owned inholdings and 17 ha (41 acres) around the Washington Memorial Chapel—areas surrounded by, but not a part of, VAFO.

accounting for 42% of the total park area. This is a sizeable fraction of the area that was in cropland and pasture at the time of the 1777–1778 winter encampment by George Washington's troops. Uncultivated grasslands and meadows are gaining recognition as vital habitats for many native plants and animals at the same time as they are becoming scarcer and the species that depend on them are undergoing alarmingly rapid declines.

These lands have been maintained against the process of natural succession since the eighteenth century, first by the resumption of farming after the military encampment and then through modification of the existing agricultural landscape into a stylized commemorative landscape during the park era (1893–present) (National Park Service 2007). In 1991, the park implemented a Field Management Plan that resulted in the park-wide establishment of "tallgrass meadows"—areas dominated by herbaceous plants that are mowed no more often than once or twice a year, regardless of the height of the vegetation (see *grassland*, *meadow* and definition 2 of *tallgrass* in *Glossary*). The primary goal of this plan was to mimic the appearance of small-grain agriculture, reminiscent of the landscape as it was in the eighteenth century. In 2007, the park completed a new General Management Plan (GMP) (National Park Service 2007), which established goals for land management in the park that differ somewhat from earlier plans. Preserving historical resources and providing visitors with a sense of the eighteenth-century agricultural landscape will continue to play a role in deciding how to manage the park's fields; however, the primary park mission goal that will guide future grassland and meadow management states:

> Significant resources (cultural resources including landscapes, buildings, monuments, structures, archeological sites, artifacts and archives and natural resources including biological, geological, water, and air resources) are preserved, rehabilitated, or restored; maintained in good condition; and managed within the broader ecosystem and cultural context. The NPS contributes to knowledge about natural and cultural resources and associated values. Management decisions about these resources as well as about visitor use are based on adequate scholarly and scientific information [National Park Service 2007]

Relevant park management objectives linked to this goal are:

- Biological resources are managed to preserve and restore natural abundances, diversities, dynamics, and distributions of native plants and animal populations within forested and other naturally occurring communities. In naturally occurring communities where species populations occur in unnaturally high or low concentrations as a result of human influences or extirpation of predators, and such occurrences cause unacceptable impacts on natural resources and natural processes, biological and physical remedial actions would accelerate natural recovery.
- Meadows are managed to enhance their high habitat values [National Park Service 2007]

These goals and objectives give a coarse-scale overview of desired conditions for the park's grasslands and meadows. The present document itemizes specific, measurable desired conditions at a finer scale. It identifies both existing and desired conditions in the park's grasslands and meadows and will serve as the foundation for strategies to narrow the gap between the two. Methods to achieve the desired grassland/meadow conditions and other park management objectives will be developed in detail and implemented through a revised Field Management Plan.

1.2 Scope

This document is a statement of science-based goals, rationales for those goals, and measurable outcomes for the restoration and adaptive management of VAFO's grasslands and meadows. The scope of the desired condition analysis encompasses:

- reviewing the natural history and conservation significance of native grasslands and meadows in the "Greater Piedmont" (see Figure 1) and in the wider Mid-Atlantic Region, focusing particularly on grassland birds and butterflies and rare or declining native species of plants and other grassland and meadow wildlife
- compiling historical documents, herbarium records, descriptions of reference sites, and other sources of information on native grassland and meadow flora and fauna in Valley Forge and the surrounding ecoregion pertinent to identifying ranges of target values for desired conditions
- compiling pertinent hypotheses and research results in historical ecology, including pre-European-settlement human influences, across the Mid-Atlantic Region
- identifying and ranking ecological indicators including ecosystem stressors and predicting probable ecological trajectories of VAFO grasslands and meadows assuming no change in management action
- defining specific, measurable desired conditions, taking into account ecological considerations and the park's mission, management goals and objectives, and resource values as summarized in the GMP
- quantifying metrics of desired conditions using the ecological integrity assessment framework (Unnasch et al. 2009)

In much of eastern North America, conducting a desired condition analysis for grasslands and meadows differs from doing the same for forestlands in a key procedural detail—the pre-European-settlement condition of the site itself is not a central issue. Instead this analysis focuses on historical (including pre-European-settlement) conditions at other grasslands and meadows in geologically similar landscapes across the Greater Piedmont. There has been little scientific study of the paleoecology of grasslands and meadows in the Northeast compared with that of its forests and wetlands, which is the subject of numerous scientific papers. The author has assembled much of the knowledge base of this report over the past 25 years while conducting experiments and other field investigations, compiling and analyzing

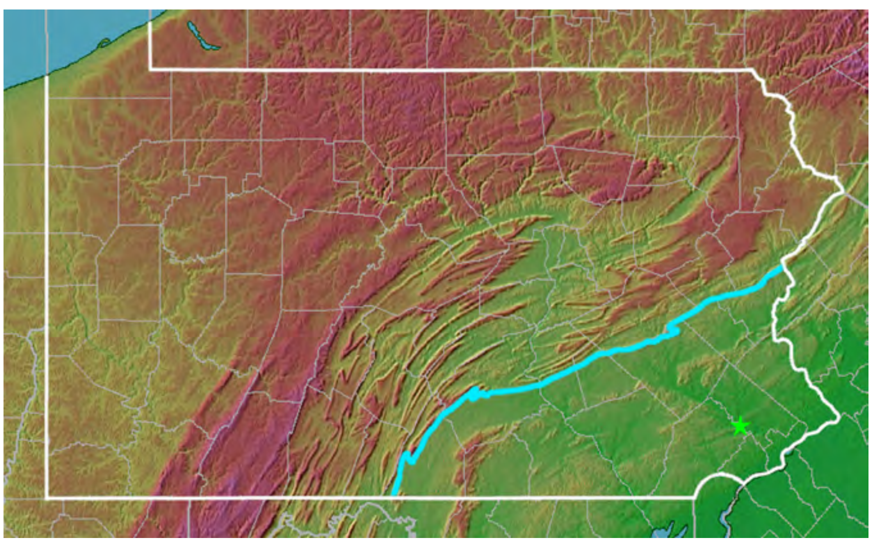

Figure 1. **The Greater Piedmont** is all of Pennsylvania southeast of Blue Mountain/Kittatinny Ridge (blue line) except for South Mountain (red area near southwest corner). With its distinctive regional species pool of plants, animals and other organisms, it is the main source of historical data and reference sites on which to model grassland and meadow reclamation in Valley Forge National Historical Park (green star). See Figure 2 (p. 9) for a detailed breakdown of ecoregions.

historical data (Latham 2005), and authoring or co-authoring various restoration and management plans involving native grasslands and meadows (e.g., Latham and Thorne 2007; Orndorff and Patten 2007; Latham 2008).

The focus in this report is the *resource* dimension of the trifecta of desired condition dimensions: resource, human and institutional (Eckert 2009). Incorporating human and institutional dimensions will require stakeholder involvement, partnerships, consideration of policies and competing values, and other complexities that are beyond the scope of the current analysis.

1.3 Objectives

The desired condition analysis for grasslands and meadows in Valley Forge National Historical Park will serve planners and land managers as a basis for decision-making, developing adaptive management strategies, and designing specific, detailed management and monitoring plans. It is intended operationally to:

- serve as a systematic, objective basis for prioritizing the urgency of management actions to mitigate threats to biological resources
- provide a method for tracking the effectiveness of adaptive conservation and resource management actions
- foster a deeper understanding among planners and land managers of the linkages between conserving grassland and meadow biodiversity and conserving ecological processes and ecosystem resilience
- provide a consistent basis for clearly articulating research and monitoring needs to further conservation objectives in support of adaptive management
- support objective comparisons over time within VAFO and between VAFO and other federally managed sites based on a common approach and vocabulary
- facilitate organizing information, conducting analyses, and reporting results within the context of the National Park Service mission, Government Performance and Results Act of 1993 (GPRA) compliance, and other reporting requirements

The desired condition analysis will contribute to the development of two key planning documents for Valley Forge National Historical Park—the Resource Stewardship Strategy (RSS) and a revised Field Management Plan. The RSS will consist of a set of science- and scholarship-based strategies to achieve and maintain the desired conditions of the park's natural and cultural resources as set forth in the GMP, this desired condition analysis and other planning documents. The RSS will serve as a basis for detailed program and project plans and for determining, over the long term, the park's budget allocations and needs for additional funding and staff capabilities. The revised Field Management Plan will translate desired conditions and other planning considerations into site-specific tasks and a timetable for their execution.

2 Site Description

2.1 Grasslands and Meadows Defined

The broad vegetation categories *grassland* and *meadow* refer to uncultivated areas dominated by herbaceous plants with soils that are not saturated year-round (permanently wet herb-dominated ecosystems are *marshes*). Grasslands have more than 50% cover by grasses; meadows have more than 50% cover by *forbs*, which is a catch-all term for herbaceous plants other than grasses or grass-like plants such as sedges and rushes. Most forbs are wildflowers, although herbaceous plants that have no flowers such as ferns are often included. Either grassland or meadow is *savanna* if scattered trees or tall shrubs make up between 10% and 25% of the total vegetation cover (expansive grassland with less than 10% tree cover is often called *prairie*). *Cover* can be thought of as the amount of ground surface shaded by plants' leaves; with 25% to 60% tree cover a plant community is classified as *woodland* and over 60% is *forest*. In practice, there is not a sharp dividing line between grassland and meadow—in many places there are patches of both types present and in some, grasses and forbs each cover about the same total area.

Throughout this document the term *grassland/meadow species* (or *specialist)* refers to any kind of plant, animal, fungus or other organism that depends for all or part of its life cycle on grassland or meadow habitat; it is used here only for species native to grasslands and meadows in the Greater Piedmont. A subcategory is *grassland birds*, also called *grassland-interior birds*. They require access to large, unfragmented grasslands or meadows to nest and successfully rear young. They succeed most reliably in grassland or meadow expanses of 40–100 ha (100–250 acres) or more, unbroken by fencerows of trees or shrubs, roads or other features.

2.2 Regional Context

The pertinent region for this study is termed the Greater Piedmont (see Figure 1, p. 5), characterized by a distinctive regional species pool of plants, animals and other organisms. It encompasses nearly all of Pennsylvania south and east of Blue Mountain, also called Kittatinny Ridge (the exception is South Mountain, near the southwest corner). It may be defined in terms of ecoregions (Woods et al. 1999a, 1999b) or physiographic provinces and sections (Sevon 2000), which share many, but not all, boundaries in common. The Greater Piedmont includes large parts of four Level IV ecoregions within the Northern Piedmont (Level III) and small portions of three other Level III ecoregions: Middle Atlantic Coastal Plain, Northeastern Highlands, and Ridge and Valley (Table 1, opposite, and Figure 2, p. 9). Data were compiled mainly from the Pennsylvania portions of the relevant ecoregions because floristic records are aggregated by state and those from within Pennsylvania have been digitized and are readily available.

VAFO itself spans the meeting point of three of the Level IV ecoregions (Figure 2): most of the park is in the Triassic Lowlands; the southernmost fringe of the park is in the Piedmont Limestone/ Dolomite Lowlands; and Mt. Misery, Mt. Joy and the gorge of Valley Creek between them are in the Piedmont Uplands. The closest point in the Middle Atlantic Coastal Plain is 23 km (14 miles) southeast of the park near East Falls in Philadelphia. The Northeastern Highlands come up to within 28 km (18 miles) of the park toward the northwest, in the hills west of

Table 1. **Level III and IV ecoregions and corresponding physiographic provinces and sections comprising the Greater Piedmont** (Woods et al. 1999a, 1999b; Sevon 2000)

Level III ecoregion	Level IV ecoregion	physiographic province	physiographic section
Northern Piedmont	Triassic Lowlands	Piedmont	Gettysburg-Newark Lowland
	Piedmont Limestone/ Dolomite Lowlands		Piedmont Lowland
	Piedmont Uplands		Piedmont Upland
	Diabase and Conglomerate Uplands		Piedmont Upland
Middle Atlantic Coastal Plain	Delaware River Terraces and Uplands	Atlantic Coastal Plain	Lowland and Intermediate Upland
Northeastern Highlands	Reading Prong	New England	Reading Prong
Ridge and Valley	Northern Limestone/ Dolomite Valleys	Ridge and Valley	Great Valley
	Northern Shale Valleys		Great Valley

Boyertown. The nearest boundary of the Ridge and Valley forms a rough arc 45 km (28 miles) north and northwest of VAFO, from Reading to the Saucon Valley south of Allentown.

Plant species composition varies widely among different communities in the Greater Piedmont and its constituent ecoregions are quite distinct geologically (Potter 1999), but communities of the same type throughout this region are more like each other floristically than they are to kindred communities in the dissimilar adjacent ecoregions. Partly because VAFO straddles three Level IV ecoregions and is close to several others, most of the plant species native to the Greater Piedmont occur somewhere nearby and are well adapted to combinations of soil and other environmental conditions found in the park itself. Certain native grassland and meadow communities in the Greater Piedmont—for instance, serpentine grasslands and mesic diabase meadows—do not have the potential to occur in the park because the types of bedrock and soil they are associated with are not present. However, very few species are restricted solely to these communities; most of their characteristic species also live in other communities where bedrock and soils are the same as or similar to those in the park.

Of 13 grassland-interior bird species nesting in the Greater Piedmont (Table 2, p. 10), only a few breed currently in VAFO grasslands and meadows (Table 7, p. 19) but any could potentially nest there if appropriate habitat is provided.

The grasslands and meadows at VAFO are almost unique in the Greater Piedmont as a block of over 400 ha (1,000 acres) of former agricultural land long maintained—since 1991 or earlier—in herbaceous cover that is not planted. (The only other comparable area is the military training corridor at Fort Indiantown Gap; Latham et al. 2007b.) The significance of this fact is that the native plant species in the park, including 172 taxa (Furedi 2008) that are grassland and meadow habitat specialists, are of locally indigenous genotypes. This genetic resource is invaluable. It will be easily and cheaply exploitable as the basis for native meadow and grassland reclamation in the park because it is under direct National Park Service control and does not need to be imported at high cost in funds and labor from other locations.

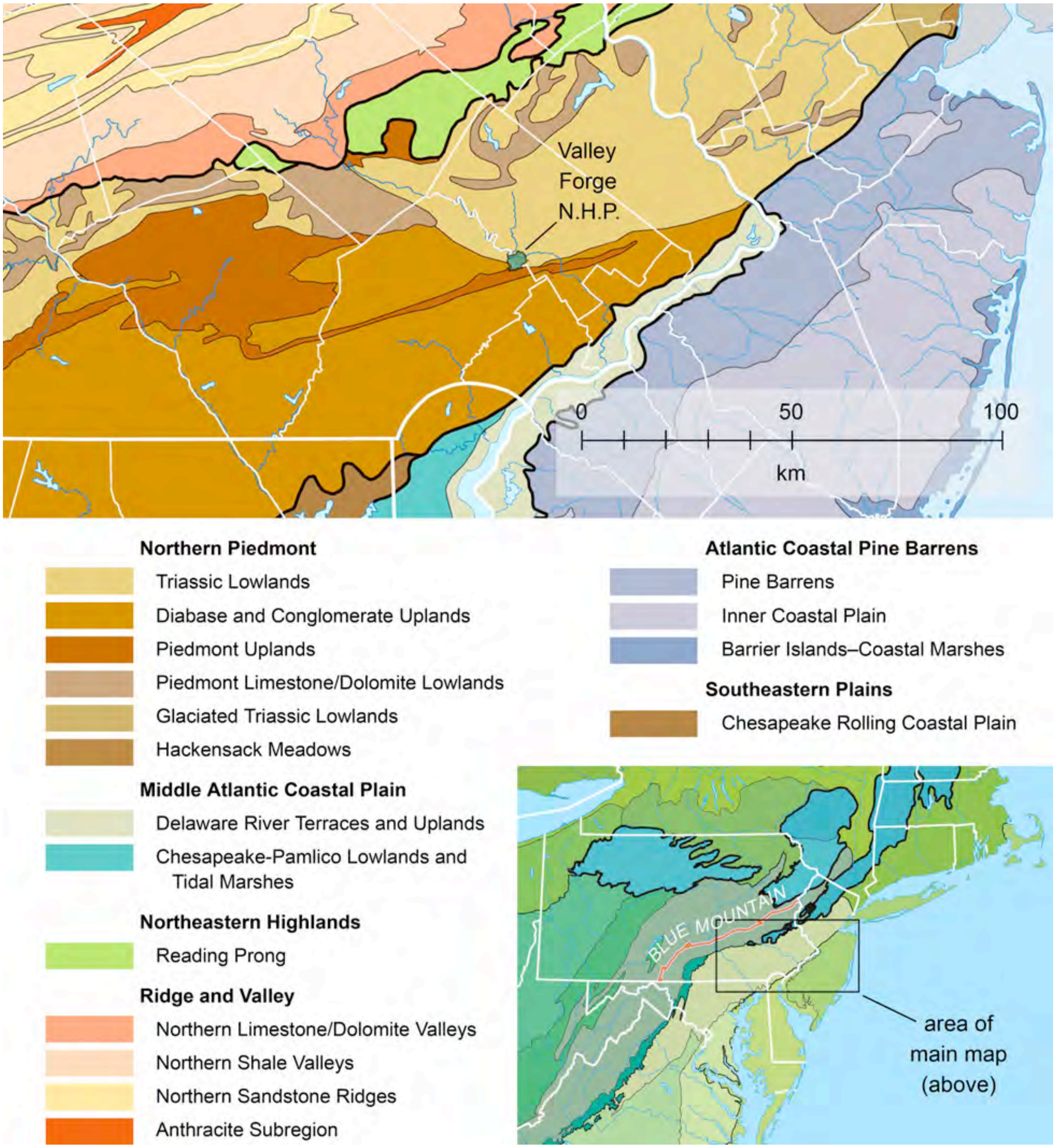

Figure 2. **Ecoregional context of Valley Forge National Historical Park** (Woods et al. 1999a, 1999b; Commission for Environmental Cooperation 2006). White lines are county, state and national boundaries. On the main map heavy black lines separate Level III ecoregions and colors denote Level IV. On the locator map heavy black lines separate the two Level I ecoregions: Northern Forests (blues) and Eastern Temperate Forests (other colors) and colors indicate Level III. (Level II ecoregions are not shown.)

Table 2. **Grassland-interior bird species breeding in the Greater Piedmont** and their conservation status (McWilliams and Brauning 2000; Mulvihill 2008; Pennsylvania Natural Heritage Program 2010c). State conservation status codes: **PE**, endangered; **PT**, threatened; **CA**, candidate at risk; **CR**, candidate rare. See Table 7 (p. 19) for species' status in Valley Forge National Historical Park.

common name	species	status in Pennsylvania
ORDER FALCONIFORMES (DIURNAL RAPTORS)		
northern harrier	*Circus cyaneus*	CA
ORDER GALLIFORMES (GALLINACEOUS BIRDS)		
northern bobwhite	*Colinus virginianus*	CA
ORDER CHARADRIIFORMES (WADERS, GULLS & AUKS)		
upland sandpiper	*Bartramia longicauda*	PT
ORDER STRIGIFORMES (OWLS)		
barn owl	*Tyto alba*	CR
ORDER PASSERIFORMES (PASSERINES)		
horned lark	*Eremophila alpestris*	
sedge wren	*Cistothorus platensis*	PT
Henslow's sparrow	*Ammodramus henslowii*	
grasshopper sparrow	*Ammodramus savannarum*	
savannah sparrow	*Passerculus sandwichensis*	
vesper sparrow	*Pooecetes gramineus*	
dickcissel	*Spiza americana*	PE
bobolink	*Dolichonyx oryzivorus*	
eastern meadowlark	*Sturnella magna*	

2.3 Bedrock and Soils

Native grassland and meadow communities in the Mid-Atlantic Region are often associated with particular types of soil and parent material. The best known of such associations is the one between serpentine grassland, a component of a community complex known as serpentine barrens, and serpentinite, the rock formation from which the underlying soils are weathered (Fike 1999; Tyndall and Hull 1999). Other examples are side-oats gramma calcareous grassland, also called xeric limestone prairie (Fike 1999; Laughlin and Uhl 2003), mesic calcareous meadow (Latham 2005), and alvar grassland (Edinger et al. 2002), all three types occurring on soils derived from limestone or dolomite; mesic diabase meadow on soils weathered from diabase (Latham 2005); ridgetop hairgrass savanna on thin soils overtop sandstone or conglomerate (Latham et al. 2007a); and American beachgrass – bitter panic-grass herbaceous vegetation, also called beachgrass – panic-grass dune grassland, on maritime sand dunes (Breden et al. 2001). Native grasslands and meadows may be reclaimed (created anew to replace other land cover) on any soil type, but similarities between land to be reclaimed and land associated with various long-established native grasslands and meadows can be used to infer which combinations of species may have the best chance of success on a given soil type.

Table 3. **Bedrock formations underlying grasslands and meadows in Valley Forge National Historical Park** (Geyer and Wilshusen 1982; Pennsylvania Bureau of Topographic and Geologic Survey 2001; Podniesinski et al. 2005). "Of total" refers to the total area of grasslands and meadows in the park and inholdings. Symbols preceding formation names correspond with those in Figure 3 (next page).

age	formation		rock types	ha	acres	of total
Cambrian	**Cah**	Antietam and Harpers Formations, undifferentiated	quartzite, phyllite, schist	99.0	244.6	16.5%
	Cch	Chickies Formation	quartzite, quartz schist, slate, conglomerate	8.1	20.0	1.3%
	Ce	Elbrook Formation	calcareous shale, silty limestone, limestone, dolomite	8.9	22.1	1.5%
	Cl	Ledger Formation	dolomite, siliceous dolomite	276.2	682.6	46.4%
Triassic	**Trs**	Stockton Formation	arkosic sandstone, siltstone, sandstone, mudstone	174.5	431.2	30.6%
Cretaceous	**Kp**	Patapsco Formation	ferruginous clay, sand	3.8	9.4	0.6%
Tertiary	**Tbm**	Bryn Mawr Formation	gravelly sand, silt	8.7	21.5	1.4%
	Tpb	Pennsauken and Bridgeton Formations, undifferentiated	feldspathic quartz sand, gravel, clay, silt	9.6	23.8	1.6%

Calcareous bedrock underlies nearly half (48%) of the grassland and meadow area in VAFO, mainly dolomites of the Ledger Formation (Cl on the map in Figure 3) and a small area of calcareous shale, limestone and dolomite of the Elbrook Formation (Ce) (Table 3). Nearly all of the grasslands and meadows on soils weathered from calcareous bedrock are south of Valley Forge Park Road (Pa. Rte. 23) and east of Mt. Joy (Figure 3). Just under one-third (31%) of the total grassland and meadow area overlies sandstone, siltstone and mudstone of the Stockton Formation (Trs), north of Valley Forge Park Road and mostly north of the Schuylkill River. Most of the rest (18%) overlies quartzite, phyllite, schist, slate and conglomerate of the Antietam and Harpers Formation (Cah) and Chickies Formation (Cch), in the western and south-central parts of the park. The remainder (less than 4%) consists of three areas underlain by unconsolidated sediments of much more recent age—gravel, sand, silt and clay of the Patapsco (Kp), Bryn Mawr (Tbm), and Pennsauken and Bridgeton (Tpb) Formations.

Information on VAFO soils at the landscape scale comes from the county soil surveys (Kunkle 1963; Smith 1967; Natural Resources Conservation Service 1999, 2004, 2007). Soils beneath grasslands and meadows in VAFO and inholdings (see Table 4, p. 14) are predominantly Alfisols (48% of the grassland and meadow area), followed by Ultisols (31%) and Inceptisols (12%). Soil great groups, suborders and orders (and their acreage proportions) are Hapludults (30%), Fragiudalfs (21%), Hapludalfs (27%), Endoaquepts (8%), Dystrudepts (4%) and Fragiudults (1%). These areas sum to just over 91% of the total grassland and meadow area. The remainder is mostly "made land," that is, soils that have been greatly altered from their native state by earthmoving for construction, landscaping, mining and the like.

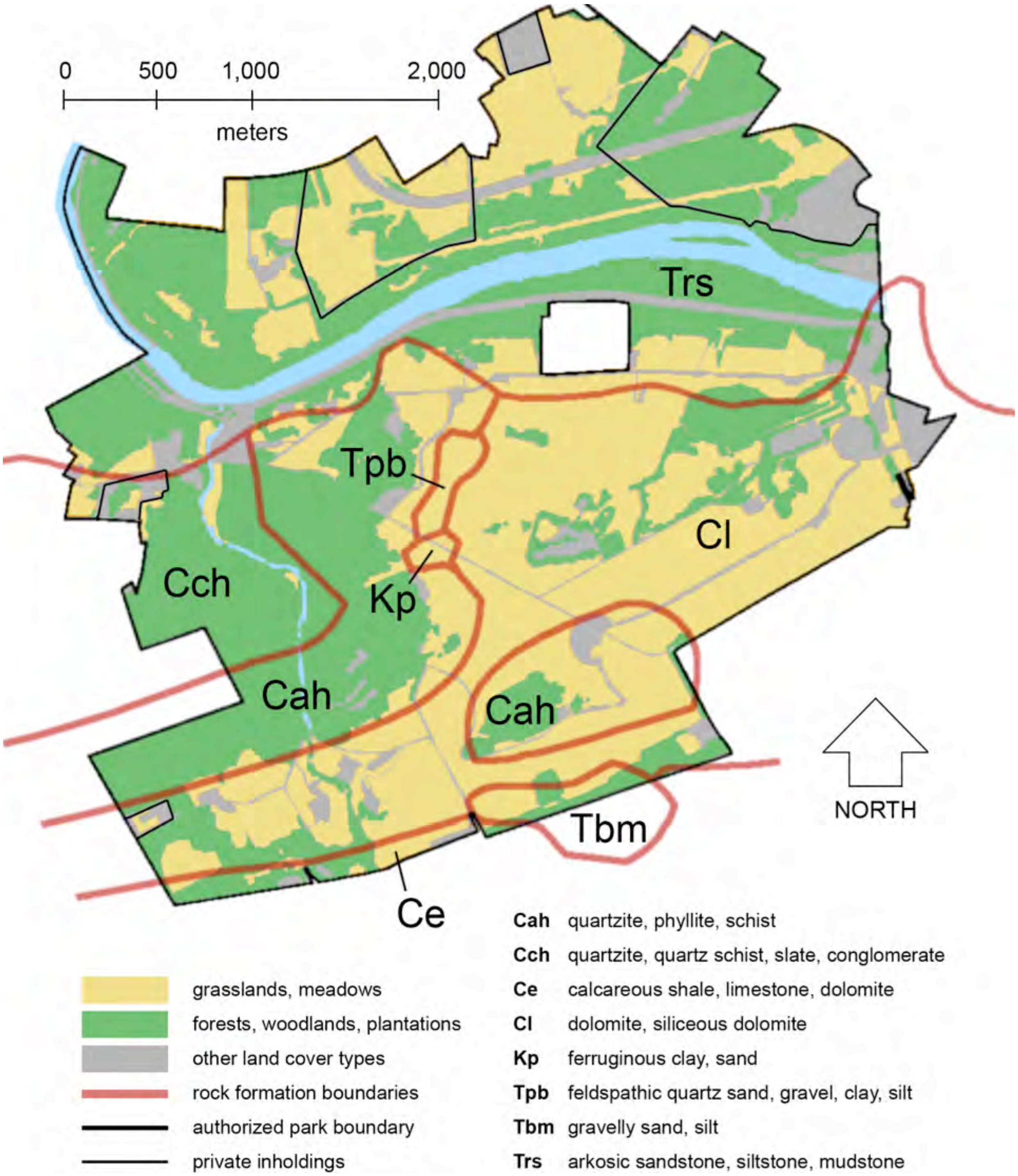

Figure 3. **Bedrock geology of grasslands and meadows in Valley Forge National Historical Park** and inholdings (Pennsylvania Bureau of Topographic and Geologic Survey 2001; Podniesinski et al. 2005)

Soils weathered from calcareous bedrock and the adjacent unconsolidated sediments tend to be described as more fertile; of the area in grassland and meadow vegetation overlying dolomite, limestone, sand and gravel, nearly two-thirds have soils classified as Alfisols (64%) with the rest almost evenly divided between Ultisols (19%) and Inceptisols (16%).

For soils weathered from non-calcareous bedrock the percentages are almost reversed, with Alfisols (39%) subordinate to the less-fertile Ultisols (51%) and Inceptisols (10%).

Soil subgroups and families show no discernible pattern with respect to bedrock type (Table 4, next page). The subgroups of soils underlying grasslands and meadows in VAFO and inholdings (and their acreage proportions) are Typic (33%), Oxyaquic (23%), Ultic (all Hapludalfs; 21%), Fluventic (Inceptisols; 8%), Fluvaquentic (Inceptisols; 4%) and Aquic (Ultisols; 3%). Likewise, soil texture is predominantly fine-loamy (62%), with areas of coarse-loamy (19%) and fine-silty (10%) soils, and cation exchange capacity is mainly active (76%), with small areas of superactive (14%) and semiactive (1%) soils.

2.4 Vegetation and Wildlife

Podniesinski and colleagues (2005) conducted a survey of vegetation throughout the park, classifying and delineating 22 plant communities and other land cover types. When community and cover types are grouped into broad landscape categories (grassland/meadow, forest/woodland, developed land/roads, and surface water), the largest fraction of the park's land is covered by grasslands and meadows (see Table 5, p. 16, Figure 4, p. 17), edging out wooded areas by two percentage points.

The survey further subdivided grasslands and meadows into several types (Table 6, p. 18). All except the old quarry/reclamation site type were described in detail in the survey report (Podniesinski et al. 2005).

Orchard Grass – Sheep-sorrel Herbaceous Vegetation, a community defined at the association level and called *grassland* for short in the survey report, makes up 86% of the total grassland and meadow area. Over 70% of it is further classified as "tallgrass" grassland, defined as seasonally mowed (once or twice per year). The remainder is termed mowed grassland, regularly mowed (several times during the growing season). Existing grassland is characterized by the

> predominance of herbaceous graminoid species and the virtual lack of woody species. Typical dominant grasses include red fescue (*Festuca rubra*), knotroot-foxtail grass (*Setaria parviflora*), [beaked] panic-grass (*Panicum anceps*), broomsedge (*Andropogon virginicus*), redtop (*Agrostis gigantea*), [meadow] fescue [*Schedonorus pratensis*], orchardgrass (*Dactylis glomerata*), and purpletop (*Tridens flavus*). Patches of vines may occur in this type, occasionally reaching several meters in diameter. Typical vines include Japanese honeysuckle (*Lonicera japonica*), wild grapes (*Vitis* spp.), oriental bittersweet (*Celastrus orbiculatus*), and poison-ivy (*Toxicodendron radicans*). Woody plants, when present, are limited to occasional seedlings and saplings resprouting after seasonal mowing. Typical woody species are apple (*Malus sylvestris*), multiflora rose (*Rosa multiflora*), and dewberry (*Rubus* sp.). [Podniesinski et al. 2005, p. 55; nomenclature updates are in brackets.]

About one-eighth of the grassland and meadow area is identified as successional old field/shrubland (areas classified as cropland in the 2005 survey are included here where cultivation was abandoned after that survey was completed). The type occurs throughout the park where former grassland or agricultural land is being invaded by shrub species.

> Shrub cover is variable from field to field but is generally greater than 20%. Typical species include autumn-olive (*Elaeagnus umbellata*), honeysuckle (*Lonicera* spp.), multiflora rose (*Rosa multiflora*), and to a lesser extent wineberry (*Rubus phoenicolasius*). Tree seedlings and saplings may also be present. Vines may be abundant in some fields as sparse to very dense patches, where they can appear as a ground cover and/or smother

Table 4. **Soil types underlying grasslands and meadows in Valley Forge National Historical Park**, classified by parent material (Kunkle 1963; Smith 1967; Natural Resources Conservation Service 1999, 2004, 2007). Only soil series and other mapping units that comprise more than 1% of the total land area are included, summing to 97.2% of grassland and meadow in the park and inholdings. Bedrock types (see Table 3, p. 11): **Cah** = Antietam and Harpers Formations, undifferentiated; **Cch** = Chickies Formation; **Trs** = Stockton Formation; **Kp** = Patapsco Formation; **Tbm** = Bryn Mawr Formation; **Tpb** = Pennsauken and Bridgeton Formations, undifferentiated; **Ce** = Elbrook Formation; **Cl** = Ledger Formation.

		mainly quartzite, schist and sandstone bedrock ha (acres)			sand and gravel ha (acres)			calcareous bedrock ha (acres)					
soil order	soil series	Cah	Cch	Trs	Kp	Tbm	Tpb	Ce	Cl	grass-land ha (acres)	% of total grass-land	higher classification (family, great group, suborder/order)	% of grass-land hydric
Ultisols	Lansdale	19.4 (48.0)		41.2 (101.7)			1.1 (2.8)		19.9 (49.3)	81.7 (201.9)	13.5%	coarse-loamy, mixed, active, mesic Typic Hapludults	—
Alfisols	Readington	6.2 (15.3)	0.4 (1.0)	1.9 (4.7)		0.1 (0.2)	4.4 (10.8)	2.3 (5.7)	55.7 (137.5)	70.9 (175.3)	11.7%	fine-loamy, mixed, active, mesic Oxyaquic Fragiudalfs	4%
Alfisols/ Ultisols	Penn and Lansdale, undifferent-iated	2.9 (7.2)	4.3 (10.5)	29.6 (73.1)		8.0 (19.8)		1.3 (3.1)	22.4 (55.4)	68.4 (169.1)	11.3%	(see under component series)	—
Alfisols	Duffield	7.5 (18.4)		2.3 (5.6)					40.1 (99.1)	49.8 (123.1)	8.2%	fine-loamy, mixed, active, mesic Ultic Hapludalfs	2%
Ultisols	Edgemont	10.7 (26.4)		30.3 (74.9)					8.4 (20.9)	49.4 (122.1)	8.2%	fine-loamy, mixed, active, mesic Typic Hapludults	3%
Alfisols	Lawrenceville	9.7 (24.1)	1.3 (3.2)	4.6 (11.3)	3.8 (9.4)		3.9 (9.6)	4.1 (10.1)	21.7 (53.5)	49.1 (121.4)	8.1%	fine-silty, mixed, active, mesic Oxyaquic Fragiudalfs	2%
Inceptisols	Bowmansville	7.8 (19.3)	0.1 (0.2)	2.2 (5.5)					38.3 (94.7)	48.4 (119.7)	8.0%	fine-loamy, mixed, active, nonacid, mesic Fluventic Endoaquepts	—
—	made land	14.8 (36.5)		3.9 (9.6)				0.5 (1.3)	17.3 (42.6)	36.4 (90.0)	6.0%		—
Alfisols	Conestoga	8.4 (20.7)		8.1 (19.9)			0.3 (0.6)		16.3 (40.3)	33.0 (81.5)	5.4%	fine-loamy, mixed, active, mesic Typic Hapludalfs	—

soil order	soil series	mainly quartzite, schist and sandstone bedrock ha (acres)			sand and gravel ha (acres)			calcareous bedrock ha (acres)		grass-land ha (acres)	% of total grass-land	higher classification (family, great group, suborder/order)	% of grass-land hydric
		Cah	Cch	Trs	Kp	Tbm	Tpb	Ce	Cl				
Alfisols	Brecknock	9.3 (22.9)				0.6 (1.4)			13.8 (34.1)	23.6 (58.4)	3.9%	fine-loamy, mixed, super-active, mesic Ultic Hapludalfs	—
Inceptisols	Codorus			12.9 (31.8)					0.5 (1.3)	13.4 (33.1)	2.2%	fine-loamy, mixed, active, mesic Fluvaquentic Dystrudepts	4%
Alfisols	Penn			4.9 (12.2)				0.2 (0.6)	4.6 (11.5)	9.8 (24.3)	1.6%	fine-loamy, mixed, super-active, mesic Ultic Hapludalfs	—
Alfisols	Duffield and Ryder, undifferent-iated			8.8 (21.7)						8.8 (21.7)	1.5%	fine-loamy, mixed, act-ive/semiactive, mesic Ultic Hapludalfs	—
Ultisols	Birdsboro	1.4 (3.5)		0.5 (1.2)					6.7 (16.6)	8.6 (21.4)	1.4%	fine-loamy, mixed, active, mesic Oxyaquic Hapludults	—
Ultisols	Mattapex			7.0 (17.4)					1.0 (2.6)	8.1 (20.0)	1.3%	fine-silty, mixed, active, mesic Aquic Hapludults	1%
—	quarries			5.6 (13.9)					2.1 (5.2)	7.8 (19.2)	1.3%		—
Alfisols	Clarksburg			6.9 (17.1)					0.4 (1.1)	7.3 (18.1)	1.2%	fine-loamy, mixed, super-active, mesic Oxyaquic Fragiudalfs	5%
Inceptisols	Rowland	0.9 (2.1)	2.0 (5.0)						4.4 (10.8)	7.3 (18.0)	1.2%	fine-loamy, mixed, super-active, mesic Fluvaquentic Dystrudepts	5%
Ultisols	Raritan			3.9 (9.6)				0.5 (1.2)	2.5 (6.2)	6.9 (17.0)	1.1%	fine-loamy, mixed, active, mesic Aquic Fragiudults	2%
	totals	99.0 (245)	8.1 (20.0)	174 (431)	3.8 (9.4)	8.7 (21.5)	9.6 (23.8)	8.9 (22.1)	276 (683)	589 (1,455)	97.2%		

Table 5. **Breakdown by area of major land cover types in Valley Forge National Historical Park** (modified from findings in Podniesinski et al. 2005).

cover type	% of park area	ha	acres
dominated by grasses, forbs, low shrubs (grasslands, meadows, savannas)	43.7%	610	1,507
dominated by trees (forests, woodlands)	41.6%	581	1,435
developed land, transportation corridors	10.5%	147	362
water	4.1%	58	143
total within VAFO authorized boundary	100.0%	1,395	3,447

> shrubs and tree saplings. Typical vine species include oriental bittersweet (*Celastrus orbiculatus*), Japanese honeysuckle (*Lonicera japonica*), and wild grape (*Vitis* spp.). The herbaceous layer is similar to the grassland type but with a higher cover of forb species. Typical grasses include broomsedge (*Andropogon virginicus*), red fescue (*Festuca rubra*), [meadow] fescue [*Schedonorus pratensis*], path rush (*Juncus tenuis*), [tapered rosette grass] (*Dichanthelium acuminatum*), timothy (*Phleum pratense*), and purpletop (*Tridens flavus*). Typical forb species include dogbane (*Apocynum cannabinum*), grassleaf goldenrod (*Euthamia graminifolia*), white snakeroot (*Ageratina altissima*), tall white beard-tongue (*Penstemon digitalis*), cinquefoil (*Potentilla* spp.), and [wrinkle-leaf] goldenrod (*Solidago rugosa*). [Podniesinski et al. 2005, p. 67; nomenclature updates are in brackets.]

Less than 1% of the grassland and meadow area is Bluejoint – Reed Canary-grass Herbaceous Vegetation, also called *wet meadow* in the park vegetation survey. Typically flooded in spring, its soils may be saturated for part of the growing season but are generally dry for much of the year. Flooding helps to keep these systems open but some are also mowed. They are described as

> open, usually graminoid-dominated meadows. On some sites, this community may be dominated by one or two species, but it is typically mixed. Representative species include rice cutgrass (*Leersia oryzoides*) wool-grass (*Scirpus cyperinus*), [northern] bugleweed (*Lycopus uniflorus*), smartweeds [*Persicaria* spp.], threeway sedge (*Dulichium arundinaceum*), marsh fern (*Thelypteris palustris*), sedges (*Carex stipata* var. *stipata, C. canescens, C. lurida, C. cristatella, C. tribuloides, C. vesicaria*), soft rush (*Juncus effusus*), Virginia chain fern (*Woodwardia virginica*), beggar's-ticks (*Bidens* spp.), dwarf St. John's-wort (*Hypericum mutilum*), joe-pye-weed [*Eutrochium* spp.], boneset (*Eupatorium perfoliatum*), cinnamon fern (*Osmunda cinnamomea*), royal fern (*Osmunda regalis*), Canadian St. John's-wort (*Hypericum canadense*), bluejoint (*Calamagrostis canadensis*), New York ironweed (*Vernonia noveboracensis*), marsh St. John's-wort (*Triadenum virginicum*), arrowhead (*Sagittaria rigida, S. latifolia*), reed canary-grass (*Phalaris arundinacea*), rattlesnake grass (*Glyceria canadensis*), black bulrush (*Scirpus atrovirens*), and spikerushes (*Eleocharis* spp.). Scattered shrubs may be present; representative species include hardhack (*Spiraea tomentosa*), buttonbush (*Cephalanthus occidentalis*), silky dogwood (*Cornus amomum*), [gray] dogwood (*Cornus racemosa*), red-osier dogwood (*Cornus sericea*), and [northern] arrow-wood (*Viburnum recognitum*). Exotic species such as purple loosestrife (*Lythrum salicaria*) and a variety of exotic grasses are frequently found in these meadows. [Podniesinski et al. 2005, p. 59; nomenclature updates are in brackets.]

Furedi (2008) conducted a more detailed survey of plant species composition in the grasslands and meadows. Analyses of the data from Furedi's study, compilation of recent botanical surveys, and analysis of historical

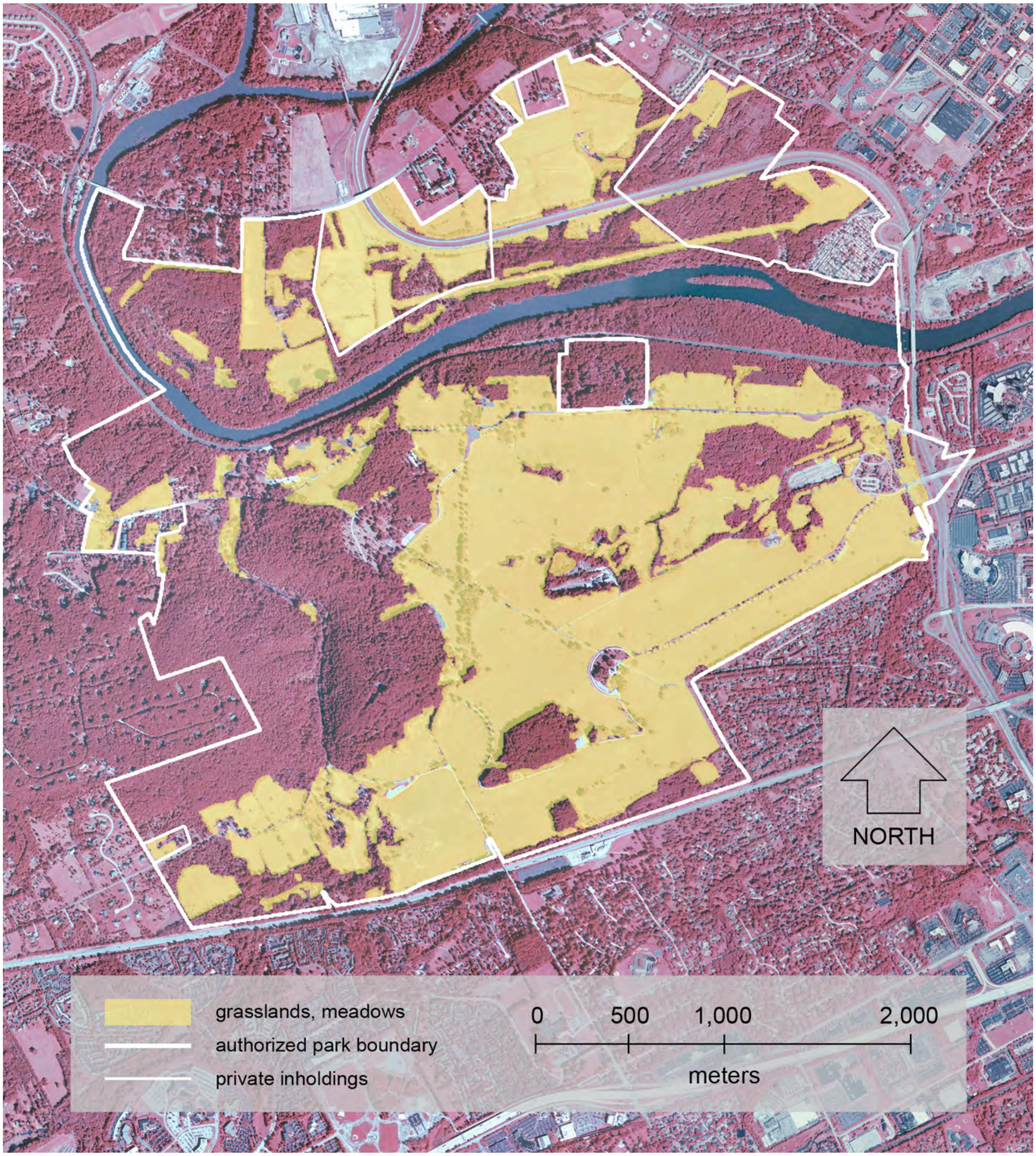

Figure 4. **Extent and location of grasslands and meadows in Valley Forge National Historical Park**. Five cover types dominated by herbaceous plants (Podniesinski et al. 2005) are superimposed on 2004 false-color infrared ortho imagery (U.S. Department of Agriculture).

Table 6. **Breakdown by area of present-day grassland and meadow community types in Valley Forge National Historical Park** (as defined in Podniesinski et al. 2005).

grassland/meadow community type	% of park area	% of grasslands and meadows	ha	acres
"tallgrass" grassland (Orchard Grass – Sheep-sorrel Herbaceous Vegetation mowed once or twice annually)	26.5%	60.7%	370	914
mowed grassland (Orchard Grass – Sheep-sorrel Herbaceous Vegetation mowed several times annually)	10.9%	25.0%	152	376
successional old field, recent cropland	5.7%	13.1%	80	197
wet meadow (Bluejoint – Reed Canary-grass Herbaceous Vegetation)	0.3%	0.8%	5	11
old quarry/reclamation site	0.2%	0.5%	3	8
total	43.7%	100.0%	610	1,507

records of plant species occurrence at Valley Forge are covered later under *Methods* and *Results*.

Formal animal surveys of the park, part of the NPS Mid-Atlantic Network Inventory and Monitoring Program, have targeted birds (Yahner et al. 2001), mammals (Yahner et al. 2006) and reptiles and amphibians (Tiebout 2003). Informal, longer-term surveys have been conducted for birds (Wolf 1996) and butterflies (Ruffin 1994; Anonymous 1996). The following paragraphs and tables summarize the survey results pertaining to the park's grasslands and meadows. The key species for defining desired conditions are grassland-interior birds and butterflies and plants and animals dependent on grassland and meadow habitats that are imperiled, rare or declining—either globally or in Pennsylvania and the Mid-Atlantic Region. This set of species is covered in detail later under *Methods* and *Results*, where an analysis drawing from many sources focuses on the habitat needs of those occurring in the park now, recorded historically, or having the potential to repopulate the park's grasslands and meadows in the future.

For birds, Wolf (1996) compiled tallies of bird sightings throughout the park for 25 years, classified by season and frequency of observation. Sightings included seven grassland-interior species, two of which were confirmed as regularly nesting in VAFO (Table 7).

Yahner and colleagues (2001) conducted point-count (60 sampling points), vehicular-road, diurnal raptor, owl and riparian surveys of birds in May 1999–May 2001 and compared them with historical records compiled by park personnel. In this three-year snapshot, they documented 163 resident and migrant species in the park (those observed most frequently in grasslands and meadows are listed in Table 8). Twenty-two are on the state list of species of special conservation concern but none of those are grassland specialists. Of 10 species documented for the first time ever at VAFO in the 1999–2001 surveys, 3 are grassland and meadow specialists—grasshopper sparrow and vesper sparrow (both nesting in the park in small numbers) and horned lark (seen rarely and only during spring migration). Birds recorded historically at VAFO but not seen during the 1999–2001 surveys include three grassland specialists—barn owl, dicksissel and northern bobwhite.

Yahner and colleagues' (2006) mammal surveys consisted of live-trapping, spotlight surveys and opportunistic observations

Table 7. **Grassland-interior bird species' status by season in Valley Forge National Historical Park, 1972–1996 and 1999–2001**. Sighting frequency codes: **C**, common; **O**, occasional; **U**, uncommon; **R**, rare—not seen every year. Letters in parentheses indicate source: **W**, Wolf's (2007) 35-year compilation, **Y**, Yahner et al.'s (2001) 3-year survey. See Table 2 (p. 10) for species' conservation status and taxonomic classification.

common name	status in park	spring	summer	fall	winter
northern harrier	?	R(W)		O(W)	
northern bobwhite	declined 1972–1996	R(W)	R(W)	R(W)	
barn owl	?	R(W)	R(W)	R(W)	R(W)
horned lark	extremely rare migrant	R(Y)			
dickcissel	extremely rare migrant				
grasshopper sparrow	?	R(Y)	R(Y)	R(Y)	
savannah sparrow	?	O(W) R(Y)		O(W) R(Y)	
vesper sparrow	extremely rare		R(Y)		
bobolink	confirmed nesting	O(W) O(Y)	O(W)	R(W) O(Y)	
eastern meadowlark	confirmed nesting; increased 1972–1996	C(W) U(Y)	C(W) C(Y)	U(W) O(Y)	U(W) U(Y)

Table 8. **Most-common bird species by season in grasslands and meadows at Valley Forge National Historical Park, 1999–2001** (Yahner et al. 2001). Data are three-year average numbers of individuals per point-count survey in areas labeled "herbaceous cover" by the survey team.

common name	species	spring	summer	fall	winter
ANSERIFORMES (DUCKS, GEESE, SWANS & SCREAMERS)					
Canada goose	*Branta canadensis*	0.7	0.6		1.9
COLUMBIFORMES (DOVES & PIGEONS)					
mourning dove	*Zenaida macroura*		1.3	0.7	
PASSERIFORMES (PASSERINES)					
barn swallow	*Hirundo rustica*	1.1	0.8		
American crow	*Corvus brachyrhynchos*		0.6	0.7	0.6
blue jay	*Cyanocitta cristata*			0.9	
eastern bluebird	*Sialia sialis*				0.7
American robin	*Turdus migratorius*	0.9			
cedar waxwing	*Bombycilla cedrorum*	0.5			
European starling	*Sturnus vulgaris*	2.7	5.4	5.2	2.3
palm warbler	*Dendroica palmarum*			0.4	
dark-eyed junco	*Junco hyemalis*				0.6
song sparrow	*Melospiza melodia*			0.4	
red-winged blackbird	*Agelaius phoeniceus*	1.2	0.9		
common grackle	*Quiscalus quiscula*	0.5			
eastern meadowlark	*Sturnella magna*	0.5	0.7		0.6
American goldfinch	*Carduelis tristis*			1.0	

Table 9. **Mammal species in grasslands and meadows at Valley Forge National Historical Park**, 2004 (Yahner et al. 2006). *Percent of total encounters* compares each species' detection rate in areas classified as grassland, wet meadow or successional habitat with its detection rate in the park as a whole, including all other habitat categories: lawn, forest and woodland, the riparian zone along the Schuylkill River, and developed areas. Percents based on small numbers of encounters are less reliable as potential clues to a species' habitat fidelity in the park.

common name	species	encounters in grasslands and meadows	percent of total encounters	classification of residency and abundance in park
white-tailed deer	*Odocoileus virginianus*	238	37	abundant breeder
white-footed mouse	*Peromyscus leucopus*	116	56	abundant breeder
meadow vole	*Microtus pennsylvanicus*	91	94	abundant breeder
gray squirrel	*Sciurus carolinensis*	17	68	common breeder
northern short-tailed shrew	*Blarina brevicauda*	16	89	common breeder
masked shrew	*Sorex cinereus*	14	88	common breeder
woodchuck	*Marmota monax*	8	80	common resident
raccoon	*Procyon lotor*	8	33	common breeder
red fox	*Vulpes vulpes*	6	20	common breeder
eastern cottontail	*Sylvilagus floridanus*	3	60	common resident
red squirrel	*Tamiasciurus hudsonicus*	3	100	uncommon/rare resident
eastern chipmunk	*Tamias striatus*	1	12	common breeder
coyote	*Canis latrans*	1	100	rare transient or resident
feral cat	*Felis domesticus*	1	14	uncommon/rare resident
striped skunk	*Mephitis mephitis*	1	100	uncommon/rare transient or resident

throughout 2004. They documented the presence of 21 species, 15 of which were seen in grasslands and meadows (Table 9). The most abundant were meadow vole, which had high fidelity to grasslands and meadows, and the habitat generalists white-tailed deer and white-footed mouse.

Tiebout (2003) conducted a reptile and amphibian inventory in the park in 1999–2002 using standard surveying methods—coverboards, drift fence arrays, substrate surveys in forest and small streams, aquatic trapping, basking turtle surveys, and frog and toad calling surveys—at 55 sampling sites (9 in tallgrass meadows), supplemented by general collecting throughout the park in locations judged likely to be productive. He documented the presence of 29 species, 11 of which were seen in areas he labeled as "tallgrass meadows" (Table 10), the only type of grassland or meadow surveyed. The most abundant species in grasslands and meadows were red-backed salamander, common garter snake and northern black racer. The species with the highest fidelity to grasslands and meadows were eastern milk snake (100% of encounters) and northern black racer (61%). The author suggested restoration programs in the park for the northern fence lizard (*Sceloporus undulatus hyacinthinus*) and black rat snake (*Elaphe obsoleta obsoleta*), both of whose habitat preferences include, but are not restricted to, grasslands and meadows.

Butterfly surveys by Ruffin (1994) and park staff (Anonymous 1996) have been conducted mainly in the park's grasslands and meadows, where the majority of species spend part or all of their life cycle. The two sources list 77 species, 14 of which are marked "uncommon," "rare" or with some other indication that they are scarce in the park. The survey lists include 17 species of special conservation concern. Special-concern species and potential species (butterflies that have been recorded nearby and throughout the Greater Piedmont) and the plants they feed on are treated later under *Methods* and *Results*.

Table 10. **Amphibian and reptile species in grasslands and meadows at Valley Forge National Historical Park**, 1999–2002 (Tiebout 2003). Species observed in habitat the surveyor labeled "tallgrass meadows" (i.e., mowed once or twice per year) are included. *Percent of total encounters* compares each species' detection rate in grasslands and meadows relative to its detection rate in the park as a whole, including all other habitat categories: lawn, forest and woodland, vernal pools, small streams, the Schuylkill River, and developed areas.

common name	species	encounters in grasslands and meadows	percent of total encounters	habitat notes
red-backed salamander	*Plethodon cinereus*	79	6	mainly forest
common garter snake	*Thamnophis sirtalis sirtalis*	26	37	habitat generalist
northern black racer	*Coluber constrictor constrictor*	14	61	also wetlands and lowland forest
northern brown snake	*Storeria dekayi dekayi*	9	47	also lowland forest
eastern milk snake	*Lampropeltis triangulum triangulum*	5	100	grasslands
eastern American toad	*Bufo americanus*	4	6	habitat generalist
northern water snake	*Nerodia sipedon sipedon*	4	6	mainly water bodies
eastern box turtle	*Terrapene carolina carolina*	2	12	mainly lowland forest
northern ringneck snake	*Diadophis punctatus edwardsii*	2	4	mainly forest
bullfrog	*Rana catesbeiana*	1	3	mainly water bodies
pickerel frog	*Rana palustris*	1	2	mainly water bodies

3 Methods

> The botanist … has no data upon which to base a statement of the plant covering of such open, treeless areas. [Harshberger 1904]

This pessimistic statement made over a century ago by University of Pennsylvania botany professor John Harshberger, in reference to "open glades and natural meadows" in southeastern Pennsylvania around the time of European settlement, fortunately is only partly true. Harshberger was right that no species list, much less an account of the relative importance of various species, has been handed down for any colonial-era grassland, meadow or fallow field in the Greater Piedmont. However, information from several sources can, in combination, serve as the basis for scientifically defensible models of the composition and structure of pre-European-settlement grasslands and meadows and eighteenth-century fallow fields. Such models are a key input for defining desired conditions.

The information used to develop desired conditions for Valley Forge National Historical Park includes:

- eyewitness descriptions from the time of European first contact and early settlement, and pertinent anthologies and interpretation by later historians
- herbarium records pertaining to grasslands and meadows in the park and region
- inventory of extant reference sites, including remnants of long-persisting native grasslands and meadows predating European settlement
- present-day distributions of plant species in Valley Forge grasslands and meadows
- present, historical and potential occurrences of all vascular plants and imperiled, rare or declining animals
- evidence from paleoecological studies pertaining to Quaternary disturbance regimes

3.1 Historical Descriptions

I searched primary and secondary sources at the Academy of Natural Sciences of Philadelphia's Ewell Sale Stewart Library, the American Philosophical Society, the Historical Society of Pennsylvania, and other repositories of historical documents pinpointed by these institutions' digital indexes. I also solicited contributions from colleagues with a professional interest in the botanical history of the region and combed through my personal compilation of books, publications and manuscripts, representing 35 years of collection effort, pertaining to the region's prehistory, history and natural history.

3.2 Herbarium Records

I extracted pertinent data from the digitized database of the Pennsylvania Flora Project (2007), which includes the records associated with approximately 400,000 voucher specimens. Compiled from all the major herbaria in the state, they represent nearly two centuries of collecting effort at over 10,000 sites in Pennsylvania. The database includes habitat information for each vascular plant taxon, which is essentially the same information presented in Rhoads and Block (2007).

Seeking useful regional generalizations from the herbarium data, I first derived a comprehensive list of the native vascular plant species characterizing grasslands and meadows across the Greater Piedmont, using a progressive series of deletions from the nearly 3,000 vascular plant taxa known to be native or naturalized in Pennsylvania (Pennsylvania

Flora Project 2007; Rhoads and Block 2007; see *Methods* and *Results* in Latham and Thorne 2007). Besides plants not documented in the wild within the Greater Piedmont, taxa were excluded that are either nonnative, aquatic or semi-aquatic, hybrids, or whose habitat description lacks any of the keywords *barren, clearing, field, grassy, meadow, open/opening, roadside, pasture, serpentine,* or *shore*, or whose habitats in the state are mainly open woods, wooded swamps, peatlands, muddy shores or tidal marshes. The 755 species remaining are *grassland/meadow species*, a term used in this document only for plants native to the Greater Piedmont.

Herbarium records were used to identify 99 historical sites in southeastern Pennsylvania with at least 10 grassland/meadow species co-occurring, omitting serpentine grasslands because of their more highly specialized floras. Of the 755 grassland/meadow species, 609 were verified historically at three or more of these sites by voucher specimens in major herbaria such as the Academy of Natural Sciences of Philadelphia (source: Pennsylvania Flora Project 2007; T. A. Block, personal communication).

With the resulting 99 sites × 609 species matrix of presence/absence data I performed detrended correspondence analysis (DCA), a type of ordination, seeking patterns in species composition relative to bedrock type and various plant traits such as wetland status. I compared the results of DCA using all native grassland/meadow species with DCA using only those classified as “occasional,” “rare” or “very rare” statewide by the Pennsylvania Flora Project, omitting those tagged “common” or “frequent” on the premise that common species might discriminate less clearly among different site types and thus may merely obscure a pattern, if one exists.

Although herbarium records are hit-or-miss with respect to Valley Forge National Historical Park—no systematic botanical survey of the area was undertaken until recently—specimens and comments written on herbarium sheets are the only data available on the historical species composition of the park’s grasslands and meadows. Herbarium records from the park and vicinity span much of the nineteenth and twentieth centuries. From these records I compiled a list of all specimens of Greater Piedmont native grassland/meadow species labeled with collection site names of places within 0.6 mile (1,000 m) of the present-day boundaries of the park. In all, 867 specimens met these criteria; the most frequent place names were Valley Forge (322 specimens), Audubon (303), Port Kennedy (66), Valley Forge Manor (49), Betzwood (44), Perkiomen Junction (40), Wetherills Corner (19) and Valley Forge National Historical Park (12).

3.3 Soil Analysis

Soil survey data (Table 4, p. 14) are limited as a tool for interpreting VAFO soils because survey descriptions of soil series and types within series are generalized across entire counties. Also, the criteria used to map soil types may differ somewhat across the county boundary bisecting VAFO because the surveys were done at different times by different authors. No detailed biogeochemical or structural analyses have been performed across the range of grassland and meadow soils in the park, but concentrations of some minerals were analyzed as part of a 2007–2008 vegetation survey (Furedi 2008). Soils were sampled from grasslands and meadows at 175 locations in a square grid with 150-m (490-ft.) spacing. Each soil sample consisted of a mixture of five subsamples taken from random locations within a 25-m^2 (270-sq. ft.) plot using a 19-mm (¾-in.) diameter probe to a depth of 40 cm (16 in.). Soil data were limited to laboratory chemical analyses.

3.4 Present-day Plant Species Diversity and Distribution

In 2007, Furedi (2008) overlaid a square grid with 150-m (490-ft.) spacing on a map of the park and conducted vascular plant surveys in the 175 resulting grid cells (each 2.25 ha or 5.56 acres) that fell within grasslands or meadows. The grid cells were independent of the traditional grassland/meadow management units in the park known as "fields" (Figure 5, p. 25). A 5-m × 5-m (25-m^2 or 270-sq. ft.) survey plot was at the center of each cell. Species in plots were identified and each one's percent cover estimated. A 15-minute meandering search in the rest of the grid cell was used to tally species not present in the plot and map the presence of nonnative invasive plants. Surveys were conducted twice, in mid-June–July and September 2007, to capture species with different phenologies.

Using Furedi's data (and methods reviewed in Magurran 2004), I analyzed vascular plant species richness at three scales. Alpha (α) is diversity within the park's grassland and meadow habitats, expressed as the average species richness of the 25-m^2 (270-sq. ft.) vegetation survey plots. Gamma (γ) is the overall diversity across the park's grassland and meadow landscape, expressed as the total species richness across all 175 plots. Beta (β) is the species turnover among habitats within the landscape, a measure of habitat diversity.

Harrison's modification of Whittaker's beta:

$$\beta_H = 100 \times (((\gamma/\alpha_{max}) - 1)/(N - 1))$$

(where α_{max} = highest number of species in any plot and N = number of plots) is an index of beta diversity among multiple plots (N) surveyed across a landscape. It is used to compare different landscapes or surveys conducted in different years in the same landscape. It can range from 0 (no turnover among samples) to 100 (every sample has a unique set of species). I computed all three statistics—α, β_H and γ—for all vascular plant species present on the plots and again for native species alone.

I calculated evenness (the inverse of dominance) among all species in each survey plot using a variation of Simpson's index:

$$E_{1/D} = 100 \times (1/\sum((n_i\,(n_i - 1))/(N\,(N - 1)))/\alpha$$

(where n_i = abundance of the ith species, N = total abundance, and α = number of species in the plot; to transform fractional percent cover quantities to integer values, I set abundance = estimated percent cover × 100). $E_{1/D}$ is independent of species richness. It can range from near 0 (one species is highly dominant) to 100 (all species are equally abundant).

I disregarded the widely used index derived from information theory by Shannon and Wiener, commonly called the Shannon index, because it confounds the two components of species diversity—richness and evenness. Different Shannon index values from multiple sites or from the same site at different times give no indication whether the disparities reflect different richness, different evenness, or both (Magurran 2004).

I calculated the proportion of total plot cover, species richness and proportion of total species richness in each 5-m × 5-m vegetation survey plot within two categories of plants—native grassland/meadow species and nonnatives. I compared medians and ranges of these statistics between the 175 plots surveyed at VAFO and 16 grassland plots surveyed using the same methods at the one reference site that is most comparable in size, land-use history and soil conditions—the military training corridor at Fort Indiantown Gap, 110 km (68 miles) west-northwest of VAFO.

In search of interpretable pattern in the current distributions of plant species across the grasslands and meadows of the VAFO landscape, I performed DCA on the plot data. Subsequently M. A. Furedi (personal communication) repeated the analysis using another ordination method, non-metric multidimensional scaling (MDS or NMS). The two methods often produce similar results but one or the other may perform poorly under

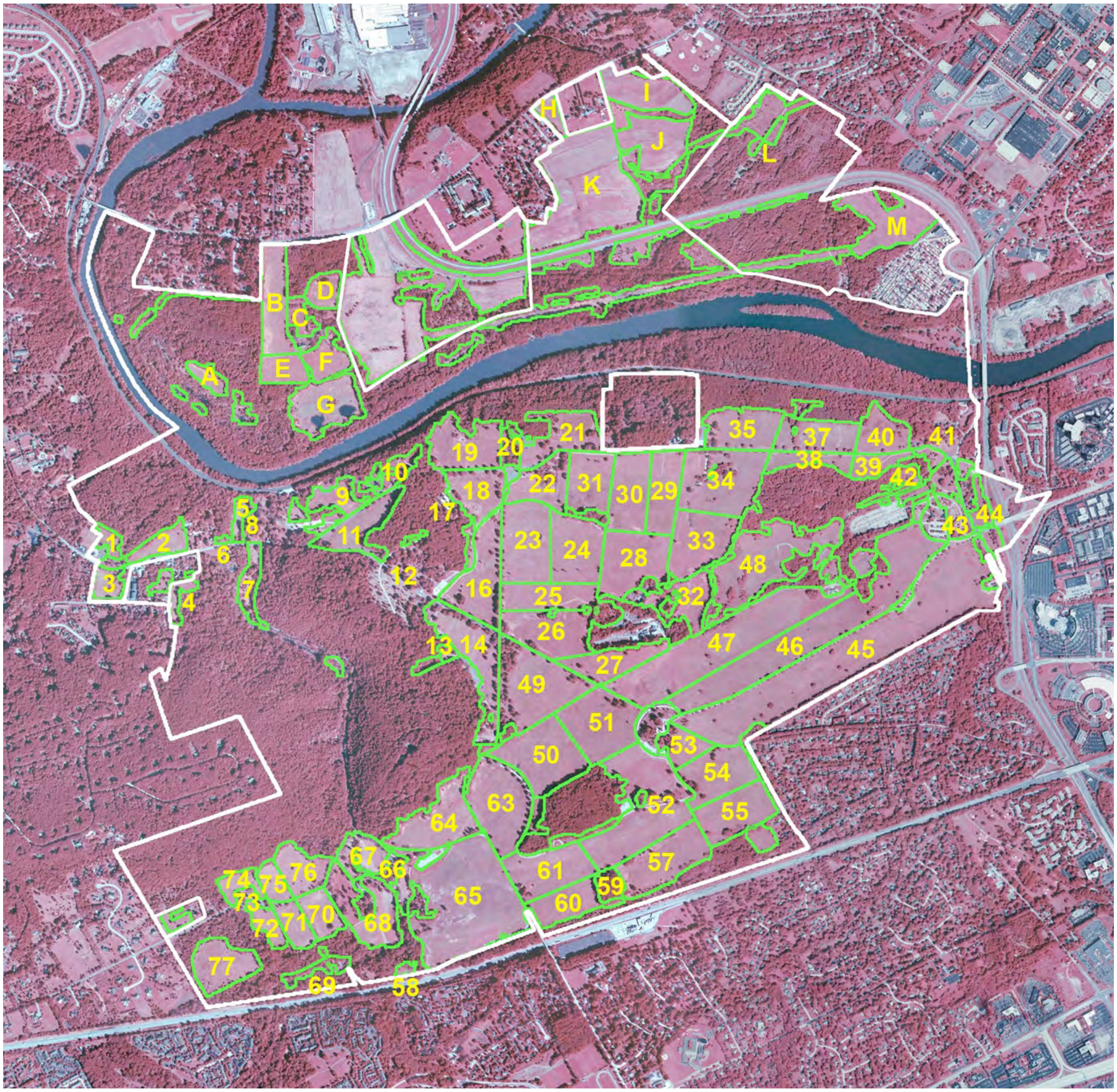

Figure 5. **Numbered fields (grassland and meadow management units) of Valley Forge National Historical Park**, superimposed on 2004 false-color infrared ortho imagery (U.S. Department of Agriculture).

certain circumstances, therefore the prudent course is to try both and compare results (Holland and Patzkowsky 2006).

I mapped the aggregate abundance in the survey plots of plant species in each of six key functional groups. The mapping units were the cells used in the survey, a grid of 2.25-ha (5.56-acre) squares, each 150 m (490 ft.) on a side. These were overlain on a base map of the grassland and meadow management units established by VAFO staff (Lambert 1992; see Figure 5, above). The functional groups are:

- native perennial warm-season grasses (11 species)
- native perennial grassland/meadow forbs and cool-season grasses (57 species)

- native annual and biennial grassland/meadow forbs and grasses (19 species)
- nonnative annual and biennial forbs and grasses (36 species)
- nonnative perennial forbs and grasses (51 species)
- nonnative woody plants (11 species)

3.5 Species of Special Conservation Concern

Species surveys have been conducted in VAFO for vascular plants (Newbold 1991–1997; Heister 1994, 1997; Podniesinski et al. 2005; Draude 2008; Furedi 2008), vertebrates (Wolf 1996; Yahner et al. 2001; Tiebout 2003; Yahner et al. 2006) and butterflies (Ruffin 1994; Anonymous 1996). From these surveys I extracted the findings on imperiled, rare or declining species living in grasslands and meadows. I also projected which additional species of special conservation concern in the same groups might potentially be present, now or in the future, using documented regional species distributions (vascular plants: Pennsylvania Flora Project 2007, T. A. Block, personal communication; vertebrates: Brauning 1992, Kirkland and Hart 1999, McWilliams and Brauning 2000, Hulse et al. 2001, Mulvihill 2008, Pennsylvania Natural Heritage Program 2010c; butterflies: Wright 2007, Pennsylvania Natural Heritage Program 2010a, B. Leppo, personal communication).

3.6 Reference Sites

I assembled a tally of present-day grasslands and meadows that are long-persisting, have never been planted, and are dominated by native grassland/meadow species. They are located in the Greater Piedmont or portions of adjacent ecoregions where the native grassland/meadow species differ very little from those of the Greater Piedmont. Sources were my own fieldwork over three decades and the collective knowledge of colleagues, including contributors to the database of the Pennsylvania Natural Heritage Program and authors of published descriptions of a few of the target communities. The intent is to provide an array of models for reclamation and potential sources of local genotypes for introduction or reintroduction of grassland/meadow species of plants and animals.

For those few reference sites where plant species inventories were conducted recently at levels of search intensity comparable to the 2007 survey of VAFO grasslands and meadows, I compared species richness of native grassland/meadow plants and nonnative plants. Only three reference sites have had plant species cover surveyed quantitatively, as in the 2007 VAFO survey. For those sites and VAFO I computed statistics for over 50 quantitative attributes suited for comparing among sites and, potentially, for choosing metrics to evaluate ecological characteristics and set targets for desired conditions.

Some of those attributes, including overall richness (γ), within-patch richness (α), within-patch evenness ($E_{1/D}$) and between-patch diversity (β_H), are explained above (p. 24). Many are simple statistics: ranges and quartiles; percentages of total species or cover within certain species categories (e.g., nonnatives or herbaceous native grassland/meadow species); and frequencies of survey plots that meet specific criteria (e.g., greater than 50% cover of native grasses or the presence of milkweeds). Other attributes calculated to compare among sites include:

- an index of relative sampling intensity = total survey plot area as a percent of the total plot area at VAFO
- an index of vegetation density = lower quartile of total plant species percent cover per plot

- another index of vegetation density = sum of all species' cover in a survey plot (can exceed 100% where plants of one species are positioned above those of another)
- an index of bare ground coverage = percent of plots where species plant cover sum to < 100%
- another index of bare ground coverage = average of 100% – total plant species cover per plot, in plots with total plant species cover < 100%
- an index of plant height diversity among patches = average relative height of herbaceous native grassland/meadow species weighted by percent cover

Relative height is defined on a scale of five height ranges or classes according to a species' typical maximum height under favorable growing conditions:

	cm	feet
1	< 50	< 1½
2	50–90	1½ –3
3	100–160	3½–5
4	170–250	6–8
5	≥ 260	9–10+

Plants often fail to reach their maximum height in the wild because of resource limitations or other constraints; nonetheless, maximum height under favorable growing conditions is a practical and readily calculable relative index of plant size across a wide range of conditions. That is because of an apparent trade-off between the capabilities of growing tall and of thriving under harsh resource limitation (Chapin et al. 1993). Species best able to tolerate low nutrients, drought or other resource scarcity are most often slower growing and shorter in stature relative to species of similar growth form. Species capable of growing tall and rapidly under favorable conditions typically are intolerant of severe resource limitation.

Average relative height of herbaceous grassland/meadow species, weighted by the percent cover of each species present, was calculated for each survey plot as:

$$\frac{\boldsymbol{\Sigma}(C_i \bullet H_i)}{\boldsymbol{\Sigma}(C_i)}$$

where C_i is the percent cover of the ith species and H_i is the height class of that species.

Analyses of relative height were restricted to native herbaceous grassland/meadow species even in plots dominated by nonnatives or woody plants. The rationale: (1) they work as indicators even if they are in the minority because they must attain close to the prevailing stature in a patch in order to compete successfully and persist much longer than a single season; and (2) they are the principal indicators of nearly all other aspects of desired condition. Similarly, analyses of shrub and small tree density were restricted to native grassland/meadow species on the basis that progressing toward desired grassland/meadow conditions will entail removal of nonnative shrub and small tree species and those mainly of forest habitats.

3.7 Quaternary Disturbance Regimes

I reviewed the paleoecology research literature pertaining to vegetation and ecological processes over the past 2.6 million years in the Greater Piedmont and the Mid-Atlantic Region, extracting material relevant to the assembly and maintenance of grassland and meadow communities during four key time periods. The intervals of interest are:

- Pre-human settlement (most of the last 2.6 million years
- Indian occupation (ca. 13,000–500 years before the present)
- European contact, Indian depopulation and early settlement (ca. 1500–1800)
- Recent (ca. 1800–present)

3.8 Desired Condition Metrics and Target Values

Those desired condition metrics and target values involving plant species diversity, percent cover of species functional groups, community structure, patchiness and habitat for butterflies of special conservation concern were developed based mainly on quantitative analyses of plant species cover data from the few relevant reference sites for which such data are available. Because so little pertinent data exist, much professional judgment is involved; therefore ranking of target values into ranges identified as “poor,” “fair,” “good” and “excellent” are not definitive, but are properly viewed as hypotheses to be tested. How well the target value ranges reflect relative quality under real-world conditions may be tested using data gathered in future years in grassland/meadow reference sites across the Mid-Atlantic Region, as well as at VAFO itself as grassland/meadow reclamation and maintenance progress. However, hypothesis testing in this case will be somewhat subjective and future adjustments to target values based on monitoring data will likewise rely to a large degree upon professional judgment and consensus among experts.

Metrics and target values at the level of whole landscapes, such as total area and contiguity of grassland and meadows in the park as a whole, were developed from a synthesis of the literature on the habitat needs of grassland-interior bird species. Target values also take into consideration the resource potentials and constraints at VAFO.

Metrics and target values for populations of plant and bird species of special conservation concern require rough estimates of abundance and distribution of each extant species within the park and are based on crude estimation of levels of abundance and patterns of distribution required for long-term population viability, given what is known about each species’ life history and other characteristics.

4 Results

4.1 Historical Context

Several historical periods are pertinent to grassland and meadow desired conditions in the park. The most recent, from about 1800 to the present, is defined by the abandonment of farming and the rise of nonnative invasive plants. The three centuries before 1800 marked the transition from mostly forest to intensive agriculture, with fields rotated through periods of fallow to permit some recovery of soil fertility. Equally important are the 2.6 million years before then—particularly the last 13,000 years—during which evolution, climate change, natural disturbance, herbivory and human impacts on the landscape gave rise to the region's native grasslands and meadows and their component species. There is no evidence confirming whether or for how long grasslands and meadows existed within the present park boundaries prior to European settlement, but several lines of evidence point to the probable combinations of species that comprised such communities and the processes most likely to have sustained them in the surrounding region.

4.1.1 The park era

VAFO began as Pennsylvania's first state park with the purchase of 89 ha (217 acres) by the Commonwealth in 1893. The Valley Forge Park Commission, the state agency responsible for the site's administration, gradually acquired additional lands and:

> … built carriage drives along the entrenchment lines, constructed an observation tower on Mount Joy, established picnic areas, and erected monuments to the brigades that had camped at Valley Forge. The commission also obliterated the existing agricultural landscape to conform to ideas of suitable grandeur. Barns and other agricultural buildings, fences, and farm lanes were removed, destroying the authentic setting and historic sense of scale. Ornamental groves of dogwoods and alleés of linden trees were planted, and Mount Joy and other areas of the park were reforested … although not in the patterns or with the species that prevailed at the time of the encampment. [National Park Service 2007]

The park was transferred to the National Park Service (NPS) in 1976. By then piecemeal land acquisition had increased the park's area to 913 ha (2,255 acres). With additional land purchases and authorized boundary changes, the park has grown to 1,340 ha (3,195 acres).

The present-day grasslands and meadows were farmed for various lengths of time beginning around 1700, when the first William Penn land grantees carved farms out of mostly forestland. Some were taken out of cultivation when the state park was established in 1893 and others have been retired gradually since then; some fields north of the Schuylkill River were still leased for cultivation as recently as 2000. Most of the park's 541 ha (1,340 acres) now in grasslands and meadows have been mowed annually since 1991. One result has been a gradual increase in the abundance of nonnative, invasive species that tolerate mowing. The increase in nonnative plant cover is steadily decreasing the overall quality and capacity of the grasslands and meadows as wildlife habitat.

4.1.2 Late eighteenth-century farming practices

The 1777 encampment turned the landscape into one dominated by mud and tents, but in the decades before and after it was a bucolic early American patchwork of cultivated and fallow fields, pastures and woodlots, with a few scattered houses, barns and other buildings. Rhoads et al. (1989) compiled information pertinent to land use within the park's current boundaries in records from the late eighteenth century, including tax records, estate inventories, deeds, depredation claims for damages by British troops during the Revolutionary War, newspapers and other miscellaneous documents. They summarized 1754–1785 data from twenty farms in and adjacent to VAFO, painting a detailed picture of how the land was used and in what proportions. Among the twenty farms, 60% had fields of wheat, 45% oats, 45% hay, 40% rye, 35% flax, 30% corn and 30% potatoes, 25% had orchards, and a few grew other crops, including buckwheat, hemp, hops, onions, turnips, cabbages and pumpkins. Of the total area in cultivation, only small fractions were devoted to livestock: sheep (4.8%), cattle (2.1%), horses (1.5%), swine (1.0%), and smaller percentages to beehives, chickens, turkeys and geese.

> The relatively low numbers of livestock indicate that animals were kept primarily to satisfy domestic needs rather than as a source of products for sale. Average holdings included four cattle and three horses. Six of the farms reported having swine with an average of six per farm. Fifteen of the farms included sheep with an average of twelve per farm. [Rhoads et al. 1989, p. 41]

Eighteenth-century fallowing practices in the region and their implications for desired conditions are covered later under *European contact, early settlement and Indian depopulation* (pp. 77-78).

4.1.3 Native grasslands and meadows throughout the Quaternary period

The time period during which the native species that exist today evolved and coevolved, underwent range shifts with climate oscillations, and gradually moved into the distributions they had around the time of European settlement is crucially pertinent to the desired condition of VAFO grasslands and meadows. The Quaternary period, roughly the last 2.6 million years, is the key time span. It has been a time of great climatic fluctuation, with fifteen to twenty cycles of continental glaciation interspersed with relatively warm periods called interglacials, the most recent of which, known as the Holocene epoch, we are living in right now. Humans have lived in the Valley Forge region for at least the last 13,000 years, longer than the Holocene epoch, the start of which is often pegged at around 10,000 years ago when the polar ice caps had melted back close to their present size.

For the purpose of analyzing vegetation development in the VAFO region, particularly of grasslands and meadows, the Quaternary period before large-scale European settlement is divided into three intervals. In reverse chronological order, with brief descriptions of the prevailing vegetation, they are:

- European contact, early settlement and Indian depopulation (ca. 1500–1777)—mainly forest, with scattered remnant grassland and meadow that had not yet reverted to forest.
- Continuous Indian occupation (ca. 13,000–500 years ago)—vegetation mosaic, mainly forest with scattered large areas of grassland and meadow; strong influence of fire on community composition and distribution, mainly due to Native Americans' use of fire to manage the landscape.
- Pre-human settlement (most of the last 2.6 million years)—alternating warm and cold climates with repeated recolonization and reassembly of temperate zone vegetation in the region; strong influence on community composition by large herbivores, most of which simultaneously became extinct around 13,000–11,000 years ago.

Information from these eras pertinent to the region's grasslands and meadows is covered later under *Quaternary disturbance regimes* (pp. 72-82).

4.2 Historical Grassland and Meadow Conditions in the Greater Piedmont

4.2.1 Early historical descriptions

The earliest surviving descriptions of vegetation in the Greater Piedmont and surrounding ecoregions date from the seventeenth and eighteenth centuries. They referred to individual species only rarely and those that did, mentioned only one or a few that caught the interest of the chronicler. The first detailed descriptions of plant communities come from the mid- to late nineteenth century. They are rare treasures for the ecological restorationist, so rare that several years of intensive searching by local historians of botanical exploration have turned up only a handful for the entire state of Pennsylvania (Latham and Rhoads 2006). The few historical descriptions that exist of the region's grasslands and meadows are the only available sources of information about the species composition of these plant communities before they were greatly altered by invasive exotic plants and introduced pathogens and herbivorous insects from other parts of the world, as well as land-use fragmentation, overbrowsing by unprecedented high deer populations, acid rain, and wildfire suppression. These descriptions are summarized in Appendix B (pp. 133-151).

Until the late 1800s, no one attempted comprehensive lists of species growing in grasslands or meadows and—except for Pehr Kalm's misidentification in 1749 of some local grassland species as the tropical *Andropogon bicorne* (Appendix B, pp. 143-144)—no one mentioned any particular grass species. A few were described but only vaguely, usually in the context of remarks on significant treeless areas or areas with sparse trees, for instance:

> The bean-grass in many places, reached up to my horses back, and stood as thick as though it had been sowed. [Near Pine Creek, Armstrong County, Pennsylvania; Ettwein 1772, reprinted in Jordan 1901]

> On each side of it [the path] as far as we could see, wild grass had grown in abundance. Some places, owing to the herbage, emitted a most fragrant smell, and we frequently had the pleasure of viewing flowers of various hues. [Near Tunkhannock Creek, Wyoming County, Pennsylvania; Rogers 1779, reprinted in 1890 in the *Pennsylvania Archives*]

> Much thick grass ... unfavorable to the growth of trees because the seeds are either swept away or rot faster than they can find lodgement on the ground. [Somerset Glades, Somerset County, Pennsylvania; Schöpf 1783-1784]

> This place ... is without a tree, or the signs of any ever being there. It produces a long grass, which soon turns yellow and perishes. [Bald Eagle Valley, Centre, Clinton or Blair County, Pennsylvania; Hazard 1831, quoted in Losensky 1961]

> Upon many of the surrounding hills ... nothing is to be met with, except the same species of long grass already taken notice of. [Near Frankstown, Blair County, Pennsylvania; Hazard 1831, quoted in Losensky 1961]

> The land was without timber, covered with a rich, luxuriant grass, with some scattered trees, hazel bushes, wild plums and crab apples. [The Barrens in Conococheague Valley, Franklin County, Pennsylvania; Day 1843; Rupp 1846]

The earliest all-inclusive species lists were compiled in the late nineteenth and early twentieth centuries. The first comprehensive survey in the region of a site that included grasslands or meadows may have been the one conducted over three years beginning in 1884 by amateur botanists John and Harvey Ruth on Wykers Island, now called Lynn Island, in the Delaware River, Bucks County, Pennsylvania. It is a unique "snapshot" of the species composition of a riverine floodplain from a time before most of the floodplain communities in the region were greatly altered by invasive plants and plant pathogens introduced from Eurasia. Of the 197 species of vascular plants documented by the Ruths, 97 were native herbaceous species typical of grasslands and meadows (Latham and Rhoads 2006). They identified 30 nonnative herbaceous species at the site, but in low numbers, in strong contrast to the overwhelming dominance of nonnative species in the site's herbaceous layer today (White and Rhoads 1996).

The most complete historical descriptions of native grassland or meadow floras in the Greater Piedmont were made about a century ago of 24 serpentine grasslands in the Piedmont uplands (Harshberger 1903; Pennell 1910, 1912). Like most botanical surveys until relatively recently, they were not quantitative. However, species inventories (Pennell 1910, 1912) were thorough, representing years of fieldwork, and major species were ranked according to dominance or relative abundance for a few sites (Harshberger 1903). By the time of these surveys, European land-use practices and imported plants had been influencing the region's flora for over 200 years, but serpentine grasslands were in all probability the least altered of native grasslands or meadows in terms of species composition because of their unusual soils, derived from serpentinite bedrock, which can greatly delay invasion by all but a very few nonnative species and most of the native species typical of forest succession. The species composition of serpentine grasslands is somewhat atypical due to those soils but the majority of plants are widespread in their distribution and occur regularly in other types of grasslands and meadows.

Generalizations supported by the information in Appendix B include:

- Grasslands and meadows were widespread at the time of European contact and early settlement, perhaps accounting for as much as 520–600 km^2 (200–230 square miles) of land scattered across the Greater Piedmont in many small and a few large tracts.
- Grassland and meadow occurred in areas underlain by a variety of bedrock types, but calcareous bedrock (mainly limestone and dolomite) may have accounted for the largest total area.
- Most areas that were called "barren" at the time of first European contact on account of their grassy or scrubby vegetation actually proved to be fertile farmland or quickly reverted to forest.
- Until European settlement, burning was common but in all likelihood highly variable in return interval, intensity and severity. A customary return interval of 3–4 years was mentioned by one source contemporaneous with Indian occupancy.
- Burning in early spring was continued into the colonial period by some residents of European descent to maintain grasslands, but the practice was discouraged by the provincial government of Pennsylvania and eventually fell out of favor.
- Grassy savanna was a common physiognomic form.
- Grass species were not identified before the late nineteenth century but early accounts make clear that tall grasses were major components in early grasslands. Upland grasses that fit the descriptions include Indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*) or eastern gamma grass (*Tripsacum dactyloides*).
- Several grassland/meadow specialist forbs that are now uncommon or extirpated in the Greater Piedmont occurred in abundance in some early grasslands, meadows or fallow fields, including lupine (*Lupinus perennis*), Indian paintbrush (*Castilleja coccinea*), orange-grass (*Hypericum gentianoides*) and pearly-everlasting (*Anaphalis margaritacea*). These examples are all short in stature, which indicates that the habitats where they were described as abundant were not densely populated with tall grasses or forbs.
- Early grasslands and meadows were characterized by a high degree of patch diversity within sites in vegetation type and plant density. Also typical were idiosyncratic differences among sites in species

composition and in the presence and relative abundance of various patch types, even between sites separated by short distances.

4.2.2 Historical grassland and meadow plant species composition based on herbarium records

Of 755 native vascular plant species considered to be grassland/meadow specialists in the Greater Piedmont (for methods used to identify them see *Herbarium records*, pp. 22-23), 333 are documented historically from VAFO and its immediate vicinity by herbarium voucher specimens. They are listed in Appendix C (pp. 153-206) with their present and historical status at Valley Forge. Omitting 15 species in the regional native grassland/ meadow flora that are narrowly restricted to specialized habitats absent in the park, the remaining 740 species are *potential* inhabitants of the park's grasslands and meadows (see Table 11, p. 34). The park is unlikely ever to harbor more than perhaps 300–400 of those species but all are included in Appendices D (527 common species; pp. 207-237) and E (213 species of special conservation concern; pp. 239-252). For each species, Appendices D and E list conservation status, wetland status, height category, tolerances of common stressful conditions, VAFO status, and frequency among historical reference sites.

To conduct exploratory analyses of historical distributions of plant species across the Greater Piedmont, from herbarium records I selected 121 sites where more than 10 of the 755 grassland/meadow specialist plants native to the region had been documented. A previous DCA of species occurrence patterns at 173 grassland and meadow sites throughout Pennsylvania demonstrated that serpentine grasslands are the "most different" from all other grassland types, dominating the ordination results (Latham 2005). Because of this, and because serpentinite bedrock—the material from which serpentine grassland soil is weathered—is absent from VAFO, 22 sites in the original tally of 121 indicator-species-rich sites in the Greater Piedmont were omitted from the present analysis.

In the 99 non-serpentine grassland and meadow sites, 609 of the native grassland/ meadow species occurred at a minimum of three sites. I performed DCA on the 99 × 609 sites-by-species matrix, and repeated with the subset of species ($N = 295$) classified statewide as "occasional," "rare" or "very rare," omitting those tagged "common" or "frequent" (Pennsylvania Flora Project 2007). The purpose of the ordination was to search for any pattern in species composition influenced by bedrock type or plant traits that may be pertinent to setting management priorities for grasslands and meadows in VAFO.

Eigenvalues were low in both analyses (609-species DCA axes 1–4 eigenvalues, respectively: 0.171, 0.144, 0.106, 0.090; 295-species DCA: 0.205, 0.160, 0.129, 0.101), indicating there is little pattern in the data. Omitting species that are common region-wide did not have a discernible effect on the results. One probable reason why the patterns are weak is that species' relative abundance (for which no historical data are available) varies considerably more among grassland and meadow community types than simple species presence. Another is that high within-site (between-patch) variation relative to between-site variation causes the signal-to-noise ratio in the ordination results to be low.

I examined scatterplots of DCA axis 1 and 2 species and site scores, with points representing sites labeled with the associated bedrock types and species labeled with traits (wetland status, maximum height, rarity status, growth form and, for grasses, warm-season or cool-season status), to see whether any meaningful clustering could be detected. The scatterplot results weakly support a few generalizations. Species of special conservation concern are disproportionately concentrated among plants around the periphery of the graph, that is, those with the highest and lowest scores on both axis 1 and axis 2. Bedrock differences between sites are apparent on axis 1—sites underlain by diabase, limestone and dolomite tend to have the lowest

Table 11. **Summary of the potential vascular flora of Valley Forge grasslands and meadows**. All taxa are native grassland/meadow specialists (listed in Appendices D and E (pp. 207, 239; see introductory text in appendices for data sources). Column A includes some taxa in Column B and all of those in Column C. Column D includes all taxa in columns A, B and C and more, but omits 15 taxa whose regional distribution is narrowly restricted to habitats that do not and will not occur at Valley Forge (e.g., serpentine grasslands). Compare with Table 12 (p. 36), which summarizes all the present and historical vascular flora of Valley Forge grasslands and meadows, including nonnatives and non-specialists.

category of vascular plants listed in Appendices D & E	A. taxa documented historically at or near Valley Forge	B. taxa present in Valley Forge National Historical Park 1991–2007	C. historical taxa not confirmed recently	D. other grassland specialist taxa indigenous to the Greater Piedmont
COMMON GRASSLAND/MEADOW PLANTS (APPENDIX E)				
common annuals & biennials	58	36	32	106
common herbaceous perennials	168	109	96	355
common woody plants	24	8	21	66
total common grassland/ meadow specialist plants	**250**	**153**	**149**	**527**
GRASSLAND/MEADOW PLANTS OF SPECIAL CONSERVATION CONCERN (APPENDIX F)				
special-concern annuals & biennials	5	3	3	39
special-concern herbaceous perennials	15	7	12	156
special-concern woody plants	3	2	1	18
total grassland/meadow plants of special conservation concern	**23**	**12**	**16**	**213**
GRAND TOTAL—GRASSLAND/ MEADOW PLANTS	**273**	**165**	**165**	**740**

scores and those with unconsolidated sand and gravel the highest, with miscellaneous bedrock (schist, gneiss, quartzite, sandstone, siltstone,shale and others) and river floodplain sites distributed about equally around the midrange, suggesting that classifying grassland and meadow communities into those three broad groups captures a large part of the variation in species composition. Subtle trends are discernible on axis 2—diabase, limestone, dolomite and sandy sites tend to have higher scores than the others, C_3 grasses score slightly higher on average than C_4 grasses, and herbaceous plant maximum height tends to be inversely related to the axis 2 score.

Species scores along both axes were divided into 10th, 25th, 75th and 90th percentiles to see if species and sites associated with particular sectors within the plots, regardless of whether any clustering is apparent, formed biologically meaningful groups based on known habitat affinities or other traits. Species close to the periphery of the graph (those with high or low scores on one or both axes) tend to be specialists on one of the three groups described in the preceding paragraph; they have a high likelihood of belonging to the set of plants that most strongly distinguish site types from one another. However, based on species' site preferences (Rhoads and Block 2007) and the author's own fieldwork, enough mismatches and omissions were noted that these results are not presented. Instead, known species tolerances of stress associated with calcareous, sandy, shaly, wet or dry soils or riparian conditions (intermittently dry and saturated soils, flood and ice scour), are listed for the 740 native grassland/meadow species listed in Appendices D and E.

The implications of these trends for reclamation and management include:

- The majority of grassland/meadow species occur in multiple grassland and meadow community types.
- A minority of grassland/meadow species are somewhat narrower in the types of sites they ordinarily occur in, which correspond to different parts of the park:
    - underlain by limestone or dolomite (e.g., most of Grand Parade, Visitor Center area, Knox's Quarters to Layfayette's Quarters);
    - underlain by quartzite, phyllite, schist, slate, conglomerate, shale, mudstone, siltstone or sandstone (e.g., Mount Misery, Mount Joy, Wayne's Woods, between Pa. Route 23 and the railroad tracks, Walnut Hill, Fatlands);
    - underlain by unconsolidated sand and gravel with some silt and clay (Conway Huts to Maxwell Brigade Encampment area and small strip along park boundary south and southeast of Wayne's Woods);
    - on the floodplains of Valley Creek or the Schuylkill River.

Species frequencies among the 99 historical reference sites roughly reflect ecological niche breadth and historical region-wide abundance. Those frequencies are listed in Appendices D and E for the 609 species in the herbarium data analysis on the premise that they may be of some value in predicting a species' likelihood of long-term persistence if present, introduced or reintroduced in the grasslands and meadows at VAFO.

4.3 Historical and Present-day Species Composition of Grasslands and Meadows at Valley Forge

The vascular flora of Valley Forge grasslands and meadows (Appendix C, pp. 153-206) consists of 361 species confirmed in 1991–2007 surveys of the park (Newbold 1991–1997; Heister 1994, 1997; Podniesinski et al. 2005; Furedi 2008) and 205 additional native plant species documented over the last two centuries by specimens collected at or adjacent to Valley Forge and deposited in major herbaria (Pennsylvania Flora Project 2007; T. A. Block, personal communication).

The 566 species belong to 290 genera in 83 families. The most diverse genera are *Carex* (41 species), *Solidago* (12) and *Symphyotrichum* (10). The most diverse families are the composites (Asteraceae, 92 species), grasses (Poaceae, 90), sedges (Cyperaceae, 55), legumes (Fabaceae, 36), rose family (Rosaceae, 28), and mints (Lamiaceae, 24).

There are 425 native and 141 nonnative species on the list, including 220 natives confirmed present within VAFO grasslands and meadows in 1991–2007. Natives that are grassland/meadow species number 333 species, 172 of which were confirmed present in 1991–2007. These 333 species are part of the park's "potential" grassland and meadow flora (see Table 11).

Other summary statistics of the park's grassland/meadow flora are given in Table 12 (next page).

Table 12. **Summary of the present and historical vascular flora of Valley Forge grasslands and meadows.** Taxa are listed in Appendix C (p. 153; see introductory text in Appendix C for data sources). Column A includes some taxa in Column B and all of those in Column C. Compare with Table 11 (p. 34), which summarizes the *potential* vascular flora of Valley Forge grasslands and meadows, including grassland/meadow species native to the Greater Piedmont but not recorded at Valley Forge.

category of vascular plants listed in Appendix C	A. taxa documented historically at or near Valley Forge	B. taxa present in Valley Forge National Historical Park 1991–2007	C. historical taxa not confirmed recently	total taxa (B + C)
NATIVE GRASSLAND/MEADOW SPECIALIST PLANTS				
native specialist annuals & biennials	63	39	35	74
native specialist herbaceous perennials	184	122	104	226
native specialist woody plants	26	11	22	33
total native grassland/ meadow specialist plants	**273**	**172**	**161**	**333**
OTHER NATIVE PLANTS				
other native annuals & biennials	14	3	12	15
other native herbaceous perennials	43	30	23	53
other native woody plants	18	15	9	24
total other native plants	**75**	**48**	**44**	**92**
SUBTOTAL—NATIVE VASCULAR PLANTS	**348**	**220**	**205**	**425**
NONNATIVE PLANTS				
nonnative annuals & biennials	27	57	—	57
nonnative herbaceous perennials	34	71	—	71
nonnative woody plants	4	13	—	13
total nonnative plants	**65**	**141**	—	**141**
GRAND TOTAL—ALL VASCULAR PLANTS	**413**	**361**	**205**	**566**

4.4 Present-day Grassland and Meadow Conditions at Valley Forge

4.4.1 Analysis of 2007 soil chemistry data

Comparing soils weathered from calcareous and non-calcareous bedrock shows results that are contrary to expectation. Median calcium and magnesium levels are lower in samples collected from soils overlying calcium and magnesium-rich dolomite and other calcareous bedrock relative to quartzite, schist, sandstone and other acidic rocks, and pH is about the same (compare the first two data columns in Table 13, p. 37). Evaluation of statistical significance is not possible because spatial autocorrelation in these data violate a basic assumption of the relevant tests (Mann-Whitney U test and other nonparametric equivalents of the *t*-test for independent samples), namely, samples of different categories are not interspersed. This is because all of the calcareous bedrock is clumped in the

Table 13. **Comparison of soil chemical characteristics among grassland and meadow survey plots grouped by bedrock and spatial criteria** (2007 data, M. A. Furedi, personal communication). Values are medians; mean and standard deviation are in brackets where data fit a normal distribution ($P > 0.05$ for χ^2 statistic). Citations in parentheses are the sources for the laboratory methods used (Brookside Laboratories, New Knoxville, Ohio).

soil attribute	calcareous bedrock ($N = 91$)	other bedrock (all samples; $N = 84$)	other bedrock (south of river only; $N = 57$)	other bedrock (north of river only; $N = 27$)
total exchange capacity (milliequivelents 100 g^{-1} of soil by dry weight; Ross 1995)	8.1	8.4 [8.8 ± 2.6]	8.3 [8.9 ± 3.0]	8.5 [8.6 ± 1.4]
pH (Watson and Brown 1998)	5.5	5.5 [5.6 ± 0.4]	5.4	5.8 [5.7 ± 0.2]
percent organic matter (Combs and Nathan 1998)	5.4	4.8 [4.9 ± 1.6]	5.5 [5.6 ± 1.3]	3.4 [3.5 ± 0.9]
phosphorus (ppm Mehlich 3 extractable; Mehlich 1984)	78	105	110	82
potassium (ppm Mehlich 3 extractable; Mehlich 1984)	210	230	244 [254 ± 119]	216 [241 ± 121]
calcium (ppm Mehlich 3 extractable; Mehlich 1984)	1,266	1,425	1,272	1,534
magnesium (ppm Mehlich 3 extractable; Mehlich 1984)	288	340	286	388 [391 ± 86]
nitrate (ppm KCl extractable; Gelderman and Beegle 1998)	12.0	4.9	5.7	3.4
ammonium (ppm KCl extractable; Gelderman and Beegle 1998)	9.7	8.7	10.7	5.7

southern half of the site. As a consequence, the trivial effect of spatial autocorrelation (the tendency of nearby samples to be more similar than more distant samples) is confounded with, and cannot reliably be separated statistically from, sources of potentially interesting effects such as bedrock chemistry. However, a closer look at the data suggests an explanation: the effects of bedrock type on soil chemistry may be obscured in the plow layer, where the samples were taken, by other influences. Splitting the non-calcareous soil samples into two groups, north and south of the Schuylkill River, reveals a pattern that appears unrelated to bedrock distribution. Calcareous soils, which are all south of the river, are more similar to the non-calcareous soils on the same side of the river than either group is to the soils north of the river (compare the first, third and fourth data columns in Table 13). Organic matter, pH, calcium and magnesium in particular show this pattern, which is likely to stem from the two areas' different recent management histories.

Based on historical settlement patterns in the region (Fletcher 1955), it is safe to assume that virtually all of the present-day grasslands and meadows at VAFO had been plowed and planted or pastured for nearly 200 years when the first tract was acquired in the late nineteenth century for what was then a state park. As tracts were added to the park, agricultural use was gradually abandoned south of the Schuylkill and replaced by mowing without harvest, but cultivation under lease continued in some VAFO fields north of the river as late as 2000 (K. M. Heister, personal communication). This historical difference may explain the higher organic matter accumulation and associated nitrogen mineralization in the fields south of the river and slightly higher pH, calcium and magnesium (likely due to continued liming) in the fields north of the river.

Data on soil moisture availability and moisture-holding capacity are not available at a scale finer than the coarse-scale mapping in the U.S. Department of Agriculture soil surveys (see Table 4, p. 14).

4.4.2 Analysis of 2007 grassland/meadow plant survey data

In a plant survey of VAFO grasslands and meadows, Furedi (2008) documented 304 of the 566 vascular plant species, subspecies and varieties recently confirmed as living in VAFO grasslands and meadows (listed in Appendix C). She quantified percent cover of 238 vascular plant taxa within survey plots (see *Methods*, p. 24), including 34 identified only to genus or family. Those 238 taxa are the subjects of the analyses reported here.

Vascular plants are classified (Tables 15 and 16, pp. 40, 41) by how commonly they occur in the park's grasslands and meadows (frequency among survey plots, irrespective of cover) and park-wide abundance (average percent cover over all survey plots). Of the 30 most common or abundant (17 are in both tables), 19 are nonnative, including the three most frequent species (Kentucky bluegrass, meadow fescue and sweet vernalgrass) and the five species with the largest total cover (stiltgrass, meadow fescue, Japanese honeysuckle, sweet vernalgrass and Kentucky bluegrass).

Across the 175 25-m^2 (270 sq.-ft.) survey plots (Furedi 2008), nonnative species accounted for 58% of species richness within plots (α),on average and 50% of grassland and meadow species richness across all plots (γ) throughout the VAFO landscape (Table 13, previous page). Habitat diversity (β) was very low (possible values range from 0–100) and differed little whether all species or only native species are considered. Evenness among species within plots ($E_{1/D}$) was relatively low on average (possible values range from 0–100) with high variation among plots. Richness data were normally distributed (χ^2 = 14.9, d.f. = 19, P = 0.73 for all species; χ^2 = 11.4, d.f. = 12, P = 0.50 for natives only). Evenness data were lognormally distributed (χ^2 = 13.9, d.f. = 13, P = 0.38; means and confidence intervals were back-calculated from $\log_e$ values).

Within plots, nonnative plants are dominant (mean cover is 68% of the total) and on average account for 52% of the species. Native grassland/meadow species occupy 28% of the plot area and account for 36% of the species (Table 14). By contrast, at the one reference site most similar in size, land-use history and soil conditions (the Fort Indiantown Gap military training corridor), nonnative species' average cover is 17% of total plot area; native grassland/meadow species occupy 78% of the area and account for 67% of the species (Table 14).

Exploratory analyses of the 238-species by 175-plot data matrix using detrended correspondence analysis (DCA) and non-metric multidimensional scaling (NMS or NMDS) yielded results of limited usefulness. High eigenvalues (DCA axes 1–4, respectively: 0.747, 0.601, 0.425, 0.330) appear to be driven by one pattern—a difference between the fields north and south of the Schuylkill River. This is probably due in part to spatial autocorrelation (the tendency of nearby samples to be more similar than more distant samples). However, it is likely also partly due to differences between the two areas' land-use histories. Most of the fields south of the river were taken out of cultivation several decades earlier than most of the fields north of the river. The younger fields, north of the river, show signs of being in an earlier successional state, with abundant annuals and relatively sparse cover by perennials and native species. The more established fields, south of the river, tend to have higher cover of perennials, especially those that spread mainly by stolons and rhizomes

The distributions of six key plant functional groups (listed on pp. 25-26) across VAFO grasslands and meadows are shown in Figures 7–11 (pp. 43-47; data from Furedi 2008; M. A. Furedi, personal communication). Distributions of several of the functional groups reflect the differences detected in the DCA and soil chemistry analyses between fields north and south of the Schuylkill: native, perennial, warm-season grasses are nearly absent north of the river (Figure 7, p. 43) but annuals and other short-lived plants reach their highest concentrations there (Figures 8 and 9, pp. 44, 45). Native perennial warm-season grasses are most abundant in the central part of the park (Figure 7). Native perennial forbs and cool-season grasses are more plentiful eastward (south of the visitors' center) and westward (south and southeast of Mt. Joy; Figure 8). Nonnative woody plants are concentrated along the park's southern margin (Figure 11, p. 47) and nonnative perennial grasses and forbs are abundant nearly everywhere (Figure 10, p. 46).

Table 14. **Vascular plant species richness and evenness in grasslands and meadows at different scales**. Data are from 175 5-m × 5-m survey plots (Furedi 2008). To calculate the figures in the second column, 98 nonnative species and 20 ambiguous taxa (identified only to a genus or family in which both native and nonnative species may be present) were omitted. For meanings of symbols and details on how values were calculated, see *Methods* (p. 24).

all vascular plants	native vascular plants only
species richness within plots α = 23.2 (average) range: 9–39 95% of plots are in range 22.1–24.2	species richness within plots α = 9.78 (average) range: 2–20 95% of plots are in range 9.19–10.37
species evenness within plots (scale: 0–100) $E_{1/D}$ = 24.8 (average) range: 7.1–52.3 95% of plots are in range 23.3–26.3	
species turnover among plots (scale: 0–100) β_H = 2.93	species turnover among plots (scale: 0–100) β_H = 2.82 (scale: 0–100)
species richness across all plots γ = 238	species richness across all plots γ = 118

Table 15. **Most-common vascular plant species in grasslands and meadows at Valley Forge National Historical Park** (Furedi 2008). Data are 2007 percent frequency among survey plots of species found on over 30% of 175 plots. Origin: **N** = native; **I** = nonnative (introduced).

species	common name	origin	percent frequency
Poa pratensis	Kentucky bluegrass	I	77.8
Schedonorus pratensis	meadow fescue	I	70.4
Anthoxanthum odoratum	sweet vernalgrass	I	69.3
Andropogon virginicus	broomsedge	N	68.2
Tridens flavus	purpletop	N	68.2
Oxalis stricta	common yellow wood-sorrel	N	68.2
Setaria parviflora	perennial foxtail	N	67.6
Celastrus orbiculatus	Oriental bittersweet	I	61.4
Microstegium vimineum	stiltgrass	I	56.8
Setaria pumila	yellow foxtail	I	54.6
Agrostis gigantea	redtop	I	52.3
Lonicera japonica	Japanese honeysuckle	I	51.7
Dactylis glomerata	orchardgrass	I	50.6
Plantago lanceolata	English plantain	I	48.9
Solanum carolinense	horse-nettle	N	48.3
Apocynum cannabinum	Indian-hemp	N	44.9
Festuca rubra	red fescue	I	42.6
Allium vineale	field garlic	I	42.0
Asclepias syriaca	common milkweed	N	41.5
Panicum anceps	beaked panic-grass	N	40.9
Dichanthelium acuminatum	tapered rosette grass	N	40.3
Linaria vulgaris	butter-and-eggs	I	38.1
Rumex acetosella	sheep sorrel	I	30.1

Table 16. **Most-abundant vascular plant species in grasslands and meadows at Valley Forge National Historical Park** (Furedi 2008). Data are 2007 average percent cover on 175 survey plots. Only species with greater than 1% average cover are listed. Origin: **N** = native; **I** = nonnative (introduced).

species	common name	origin	average percent cover
Microstegium vimineum	stiltgrass	I	17.9
Schedonorus pratensis	meadow fescue	I	17.4
Lonicera japonica	Japanese honeysuckle	I	16.0
Anthoxanthum odoratum	sweet vernalgrass	I	15.0
Poa pratensis	Kentucky bluegrass	I	12.4
Andropogon virginicus	broomsedge	N	10.1
Festuca rubra	red fescue	I	9.9
Tridens flavus	purpletop	N	8.9
Panicum anceps	beaked panic-grass	N	8.3
Dactylis glomerata	orchardgrass	I	5.0
Ageratina altissima var. *altissima*	common white snakeroot	N	4.6
Artemisia vulgaris	common mugwort	I	4.5
Elymus repens	quackgrass	I	4.4
Agrostis gigantea	redtop	I	4.2
Asclepias syriaca	common milkweed	N	3.8
Setaria parviflora	perennial foxtail	N	3.7
Celastrus orbiculatus	Oriental bittersweet	I	3.5
Setaria pumila	yellow foxtail	I	2.4
Arrhenatherum elatius var. *biaristatum*	tall oatgrass	I	2.4
Linaria vulgaris	butter-and-eggs	I	2.2
Apocynum cannabinum	Indian-hemp	N	2.1
Muhlenbergia schreberi	nimble-will	N	2.0
Bromus commutatus	hairy chess	I	2.0
Phleum pratense	timothy	I	1.4

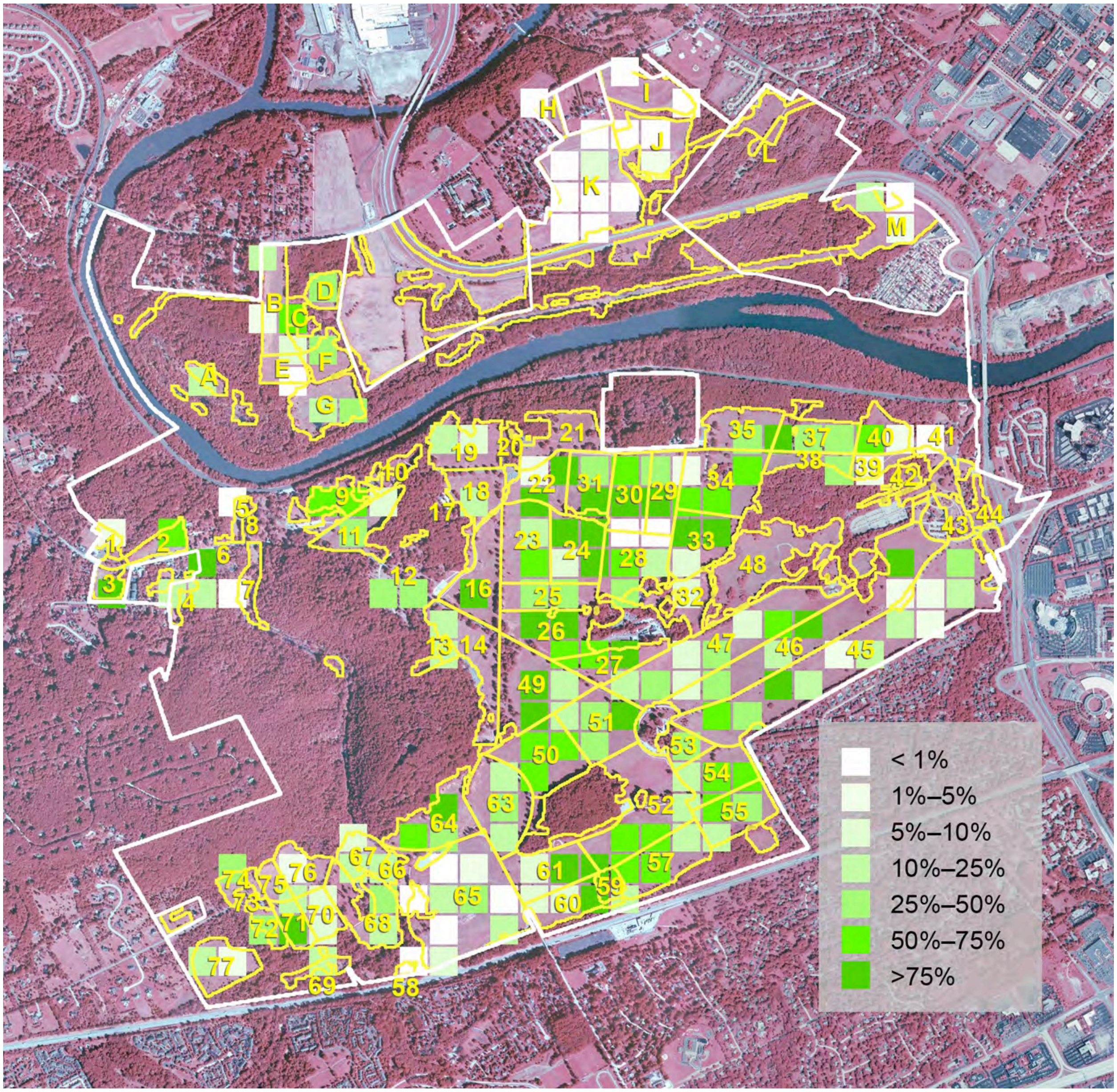

Figure 6. **Distribution of native perennial warm-season (C_4) grasses in Valley Forge National Historical Park grasslands and meadows** (11 species) as aggregate percent cover in the 5-m × 5-m survey plot at the center of each 150-m × 150-m grid cell.

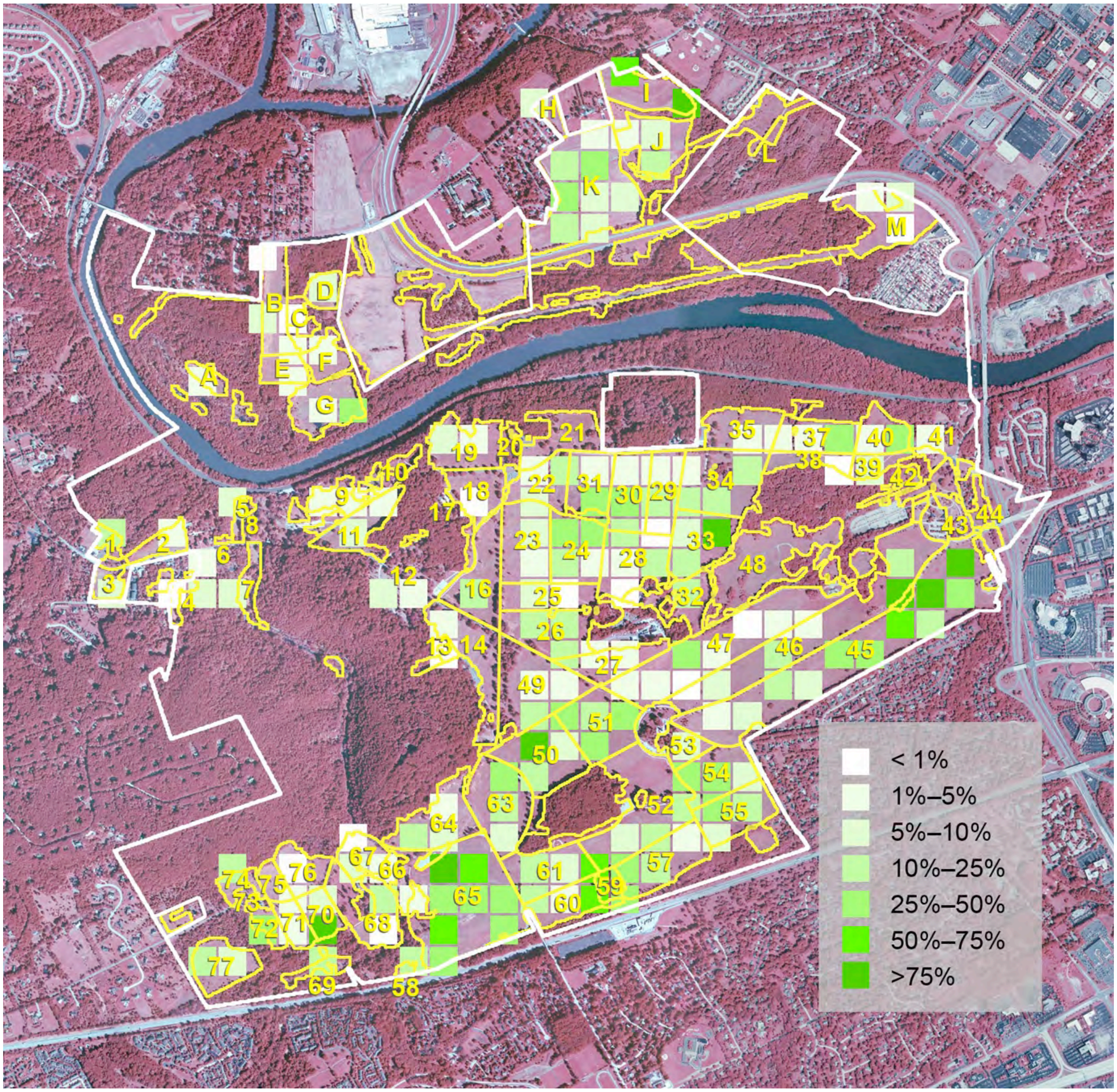

Figure 7. **Distribution of native grassland/meadow perennial forbs and cool-season (C_3) grasses in Valley Forge National Historical Park grasslands and meadows** (57 species) as aggregate percent cover in the 5-m × 5-m survey plot at the center of each 150-m × 150-m grid cell.

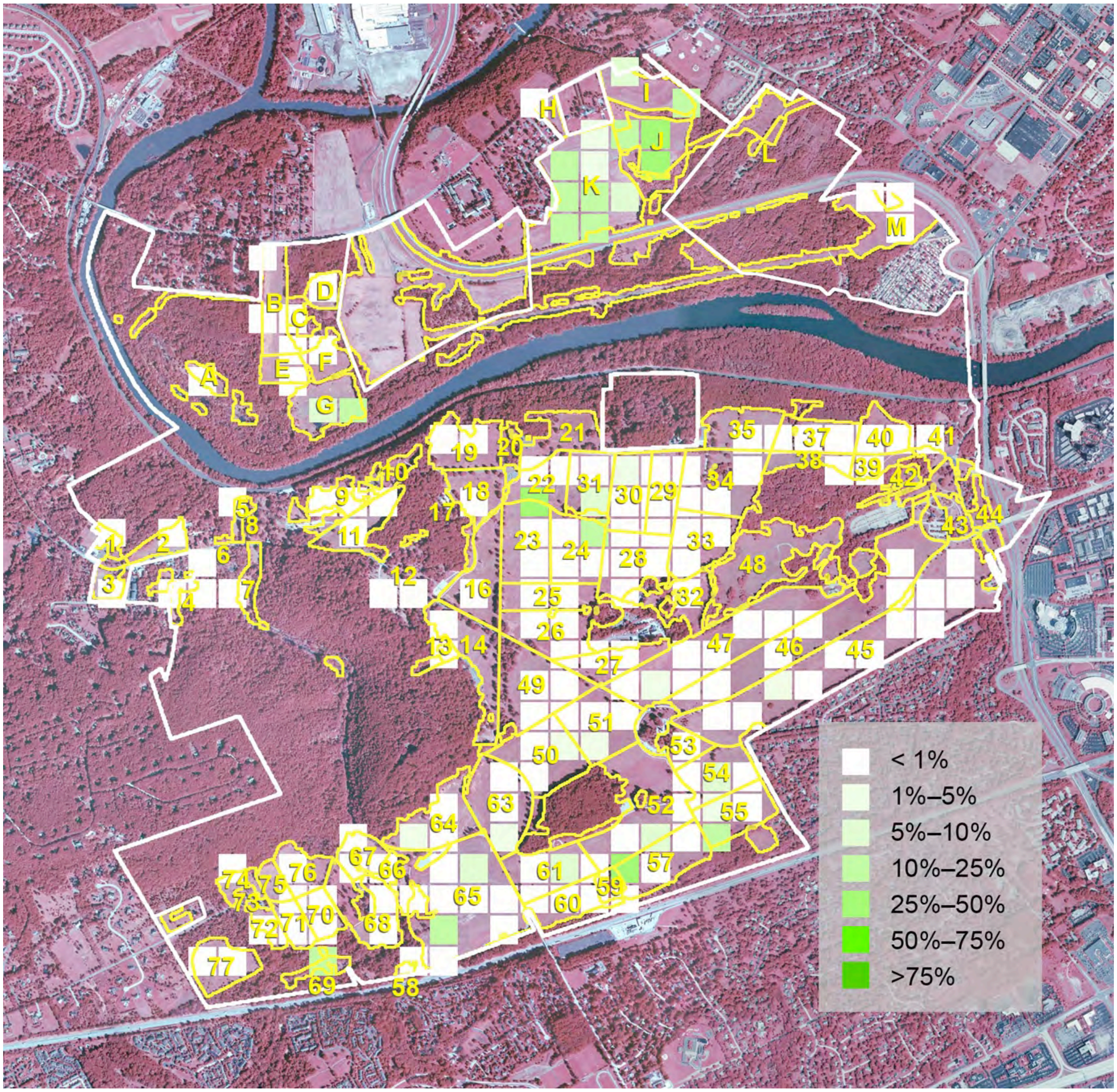

Figure 8. **Distribution of native grassland/meadow annual, biennial and short-lived perennial forbs and grasses in Valley Forge National Historical Park grasslands and meadows** (19 species) as aggregate percent cover in the 5-m × 5-m survey plot at the center of each 150-m × 150-m grid cell.

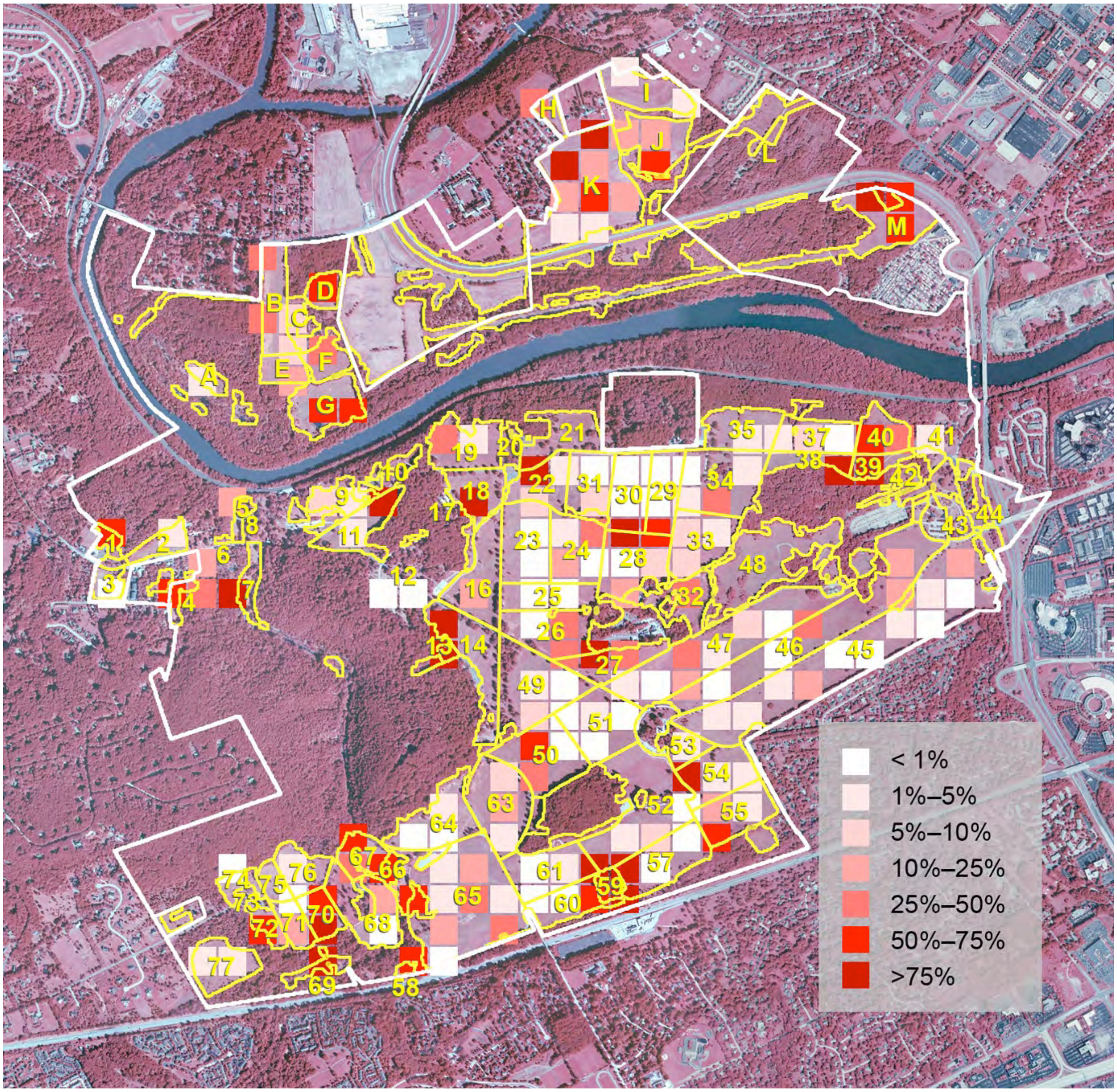

Figure 9. **Distribution of nonnative annual, biennial and short-lived perennial forbs and grasses in Valley Forge National Historical Park grasslands and meadows** (36 species) as aggregate percent cover in the 5-m × 5-m survey plot at the center of each 150-m × 150-m grid cell.

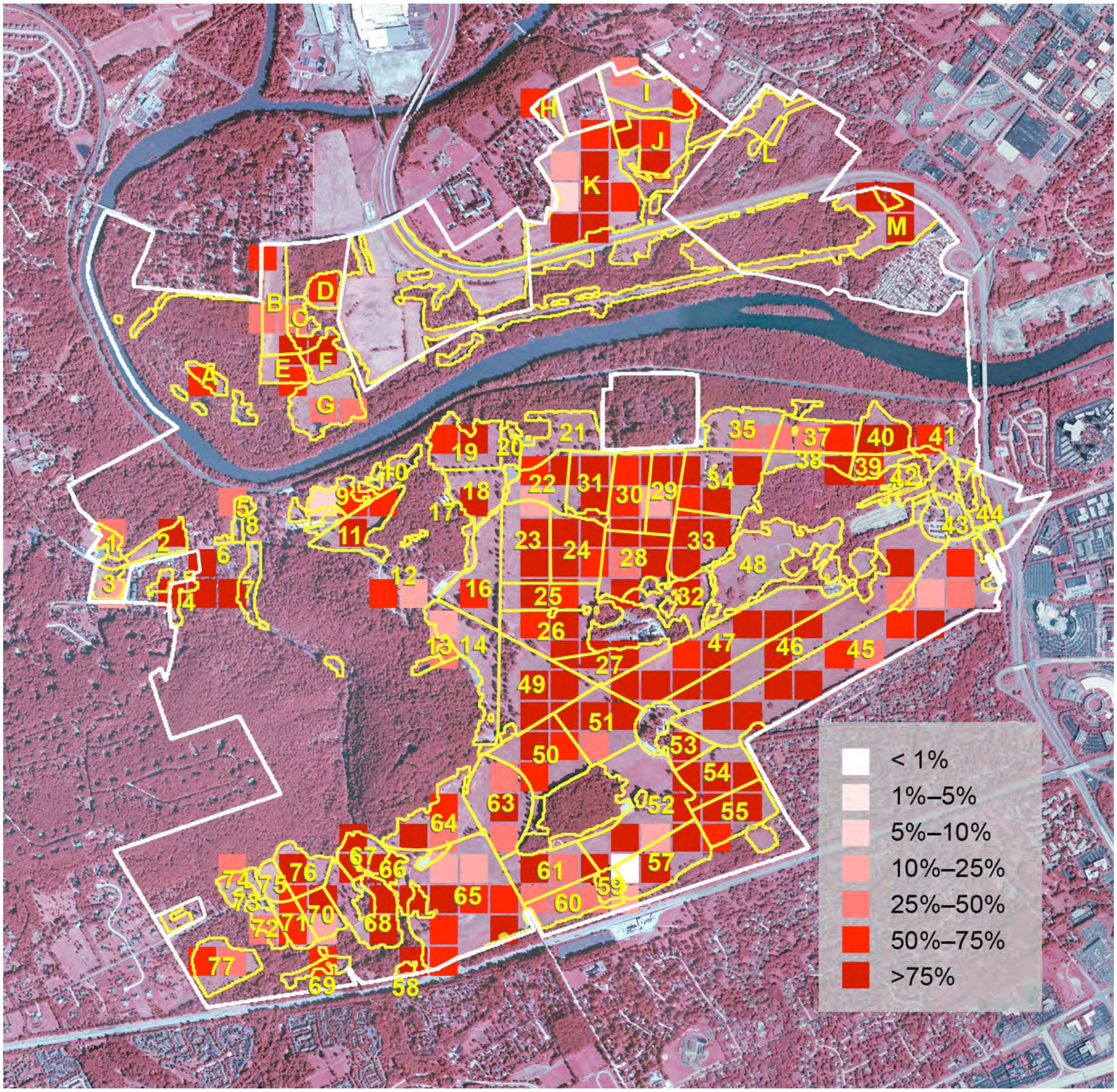

Figure 10. **Distribution of nonnative perennial forbs and grasses in Valley Forge National Historical Park grasslands and meadows** (51 species) as aggregate percent cover in the 5-m × 5-m survey plot at the center of each 150-m × 150-m grid cell.

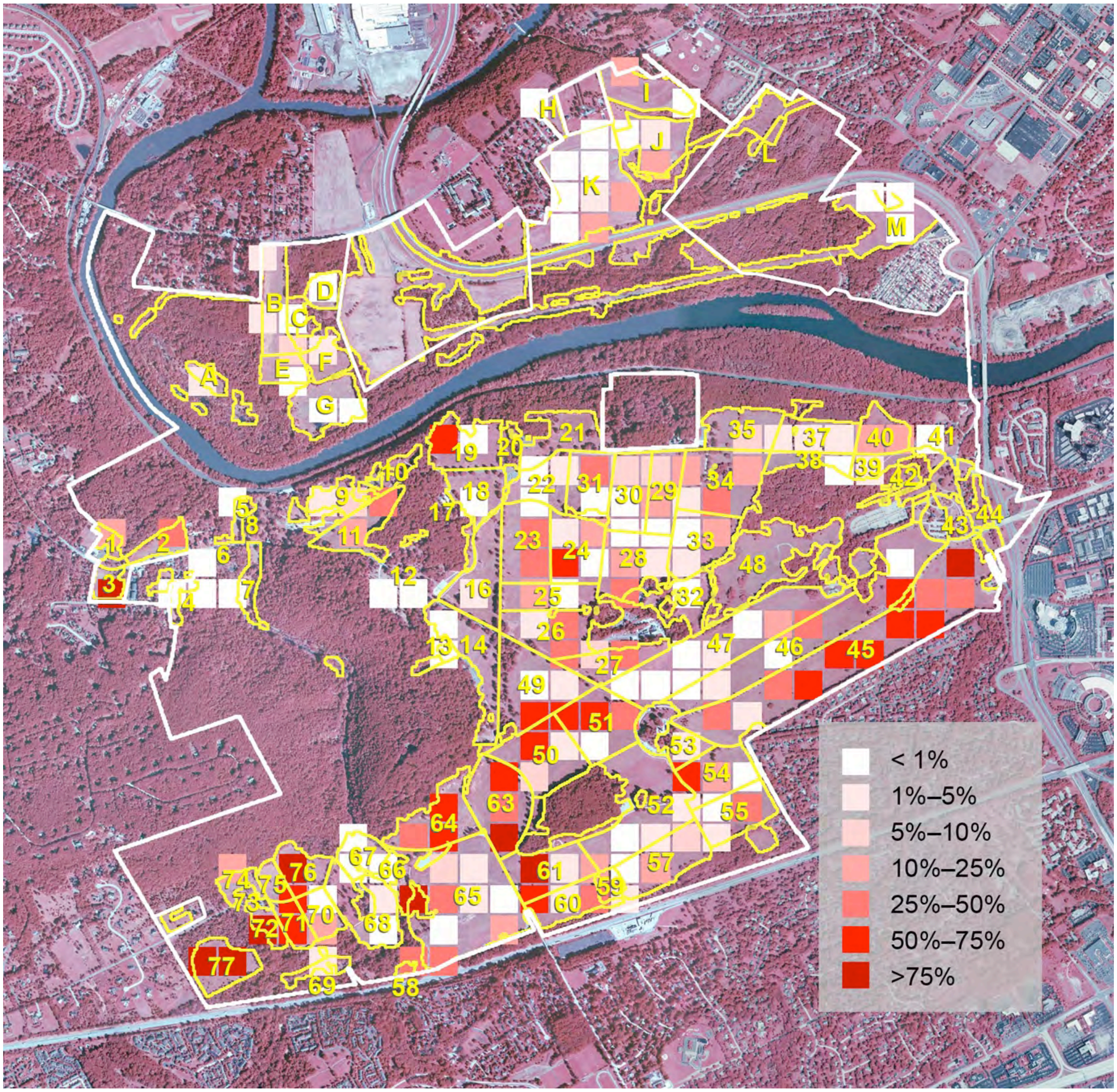

Figure 11. **Distribution of nonnative woody plants in Valley Forge National Historical Park grasslands and meadows** (11 species) as aggregate percent cover in the 5-m × 5-m survey plot at the center of each 150-m × 150-m grid cell.

4.4.3 Rare, imperiled or declining plant and animal species

Sixty species of special conservation concern (endangered, threatened, rare or declining, as defined by the Pennsylvania Biological Survey, Pennsylvania Natural Heritage Program, Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission) have been documented recently as living in VAFO grasslands and meadows. Of these, 14 are vascular plants, 25 are birds (including nesting birds, seasonal migrants, visitors and winter residents), 3 are amphibians, 1 is a turtle, and 17 are butterflies. Another 17 rare grassland/meadow vascular plant species were documented historically in grasslands and meadows at or close to Valley Forge. Little is known about the conservation status of species belonging to other groups—either within the park or region-wide—including most species of insects, other arthropods, other invertebrate groups, fungi, lichens and non-vascular plants.

An additional 213 plant, 4 bird, 2 mammal, 2 amphibian, 4 reptile and 23 butterfly species of special conservation concern that depend on grassland/meadow habitats are documented as living elsewhere in the Greater Piedmont. Some might be present but still undiscovered in VAFO or they may colonize on their own. Most are candidates for introduction or reintroduction to the park.

The 31 vascular plant species of special conservation concern documented recently or historically at Valley Forge are listed in Table 18 (pp. 49-51); 213 special-concern plant species considered as potential residents of the park are listed in Appendix E (pp. 239-252). Documented and potential birds of special conservation concern in the park's grasslands and meadows are listed in Table 19 (pp. 52-55), other vertebrates in Table 20 (pp. 56-57), and butterflies in Table 21 (pp. 58-60). Vascular plants, birds and butterflies are the main targets for identifying desired conditions for the park's grasslands and meadows. They are also central to establishing the metrics that will be used to evaluate restoration and management progress and pinpoint needs for fine-tuning management methods.

Table 17. **Species of special conservation concern in grasslands and meadows tallied by major plant and animal groups**. Survey sources are listed in the captions to Tables 18–21. See Tables 18–21 (pp. 49-60), Appendix C (pp. 153-206) and Appendix E (pp. 239-252) for lists of species and key attributes.

taxonomic group	species confirmed recently in VAFO grasslands and meadows	other species documented historically in grasslands and meadows in or very near VAFO	additional species potentially in VAFO grasslands and meadows (documented elsewhere in the Greater Piedmont)
vascular plants	14	17	213*
birds	25‡	0	4‡
mammals	0	0	2
frogs and toads	3	0	2
turtles	1	0	0
snakes and lizards	0	0	4
butterflies	17	‡	23

* Excludes species narrowly restricted to communities not present at Valley Forge, e.g., serpentine grasslands.
‡Includes nesting birds, seasonal migrants, visitors and winter residents.
‡ Historical records have not been comprehensively georeferenced or databased.

Table 18. **Vascular plants of special conservation concern documented in grasslands and meadows in or near Valley Forge National Historical Park** (Newbold 1991–1997; Heister 1994, 1997; Podniesinski et al. 2005; Pennsylvania Flora Project 2007; Furedi 2008; T. A. Block, personal communication). An additional 213 vascular plant taxa of special concern that typically inhabit grasslands and meadows (excluding those narrowly restricted to grassland or meadow types not present at Valley Forge) are present elsewhere in Pennsylvania's Greater Piedmont (see Appendix E, pp. 239-252).

taxon[1]	common name(s)	habitat and distribution[2]	PABS status[3]	growth form[4]	C_3/C_4[5]	Valley Forge status[6]
Andropogon glomeratus	bushy bluestem	Swamps and moist meadows	PR	HP	C_4	present
Andropogon gyrans	Elliott's beardgrass, Elliott's bluestem	Dry or moist fields or open woods	PR	HP	C_4	present
Aristida longespica var. *longespica*	slender three-awn, slimspike three-awn	Dry, sandy soils	TU	HA	C_4	present
Baccharis halimifolia	groundsel-tree, eastern baccharis	Open woods, marshes and roadside ditches where de-icing salts are used (adventive from nearby coastal habitats)	PR	SD		historical
Carex conjuncta	soft fox sedge	Moist open woods, fields and meadows	SP	HP		present
Carex leavenworthii	Leavenworth's sedge	Fields, meadows, pastures and clearings	SP	HP		present
Carex nigromarginata	black-edge sedge	Dry woods and clearings	SP	HP		historical
Carex tonsa var. *tonsa*	shaved sedge	Rock ledges, roadside banks and abandoned fields	SP	HP		historical

(Table continued on next page.)

[1] Nomenclature follows Rhoads and Block 2007.
[2] Pennsylvania Flora Project 2007
[3] Pennsylvania Biological Survey recommended state status: **PE** = endangered; **PR** = rare; **TU** = status tentatively undetermined and under study; **SP** = special population—relatively scarce and significant for reasons such as ecological importance, recent decline, vulnerability, role as host for imperiled animal species, or occurrence in Pennsylvania as a high proportion (~10% or more) of the range-wide population (Pennsylvania Natural Heritage Program 2010b)
[4] **HA** = herbaceous annual; **HP** = herbaceous perennial; **SD** = deciduous shrub; **VA** = annual vine; **VP** = perennial herbaceous vine
[5] Grasses only: $\mathbf{C_3}$ = cool-season; $\mathbf{C_4}$ = warm-season
[6] **historical** = collected at or in the near vicinity of Valley Forge and vouchered in a major herbarium; **present** = confirmed recently (2000 or later) within Valley Forge National Historical Park

taxon[1]	common name(s)	habitat and distribution[2]	PABS status[3]	growth form[4]	C_3/C_4[5]	Valley Forge status[6]
Conoclinium coelestinum	blue mistflower, wild ageratum	Old fields, meadows and stream banks, also cultivated and occasionally escaped	SP	HP		present
Cuscuta campestris	five-angled dodder	Thickets and waste ground, parasitic on various hosts	PT	VA		historical
Desmodium laevigatum	smooth tick-clover, smooth ticktrefoil	Dry, sandy woods and roadsides	TU	HP		historical
Desmodium obtusum	stiff tick-clover, stiff ticktrefoil	Dry, open woods, on sandy soils	TU	HP		historical
Digitaria filiformis	slender crabgrass	Dry, open sites	SP	HA	C_4	present
Eleocharis engelmannii	Engelmann's spike-rush	Vernal ponds, moist ditches and roadsides	SP	HA		historical
Hypericum stragulum	St. Andrew's-cross	Open woods, banks and thickets, in dry sandy soil	PT	SD		present
Lechea minor	thymeleaf pinweed	Rocky woods and slopes, in dry, sandy soil	TU	HP		historical
Lespedeza angustifolia	narrowleaf bush-clover, narrowleaf lespedeza	Moist, open, sandy soil of an abandoned gravel pit	PE	HP		present
Linaria canadensis	old-field toadflax, Canada toadflax	River banks, sandy fields and railroad embankments	SP	HA		historical
Lupinus perennis	blue lupine, sundial lupine	Alluvial sand and gravel bars, open fields, woods edges and roadsides in sandy soils	PR	HP		historical
Matelea obliqua	anglepod, oblique milkvine, climbing milkvine	Mesic woods, wooded edges and red cedar thickets on limestone	PE	VP		historical
Persicaria amphibia	water smartweed	Muddy shores and margins of ponds, streams or rivers	SP	HP		present
Phaseolus polystachios	wild kidney-bean, slimleaf bean	Woods, roadside banks and waste ground	PE	VP		historical
Prenanthes serpentaria	lion's-foot, cankerweed	Dry woods, clearings and gravelly roadsides	TU	HP		historical

taxon[1]	common name(s)	habitat and distribution[2]	PABS status[3]	growth form[4]	C_3/C_4[5]	Valley Forge status[6]
Pycnanthemum clinopodioides	basil mountainmint	Dry slopes	TU	HP		historical
Rotala ramosior	tooth-cup, lowland rotala	Wet, sandy shores and other swampy, open ground	PR	HA		historical
Rubus cuneifolius	sand blackberry	Dry, open thickets and roadsides, in sandy soil	PE	SD		present
Sparganium androcladum	branching bur-reed, branched bur-reed	Wet meadows, swales, stream banks and shallow water	PE	HP		present
Stylosanthes biflora	pencil-flower, sidebeak pencilflower	River banks, rocky or shaly slopes and sandy fields	PE	HP		historical
Symphyotrichum dumosum	bushy aster, rice button aster	Open woods, moist fields, bogs and swales	TU	HP		historical
Tripsacum dactyloides	gammagrass, eastern gamagrass	Swamps and wet shores (Occurrence in the park may not be a locally indigenous population; needs investigation.)	PE	HP	C_4	present
Vernonia glauca	Appalachian ironweed, tawny ironweed, broadleaf ironweed	Dry fields, open slopes or clearings	PE	HP		present

[1,2,3,4,5,6] See footnotes on p. 49.

Table 19. **Birds of special conservation concern recently confirmed in or potentially inhabiting grasslands and meadows in Valley Forge National Historical Park** (Brauning 1992; McWilliams and Brauning 2000; Mulvihill 2008)

common name	taxon	specific habitat requirements[1]	CWCS rank[2]	PABS status[3]	grassland-interior species[1]	Partners in Flight status and regional priority level[4]	recent VAFO status[5]
BIRDS							
tundra swan	*Cygnus columbianus columbianus*	For migrants, large fields (greater than 40 acres) with grass seed and other foraging material	maintenance concern; Pennsylvania responsibility				extremely rare winter resident
northern harrier	*Circus cyaneus*	Large grasslands, marshy meadows and riparian woodlands	high-level concern	CA	•		occasional/ common visitor; rare/occasional migrant
northern bobwhite	*Colinus virginianus*	Moderately dense grasses and forbs with scattered shrubs and brambles	immediate concern	CA	•	2: immediate management	rare visitor & migrant
upland sandpiper	*Bartramia longicauda*	Large-scale grasslands with a patchy mosaic of tall and short grasses and forbs and areas lacking ground litter	immediate concern	PT	•		not seen
solitary sandpiper	*Tringa solitarius*	For migrants, grassy and muddy shorelines of marshes, woodland streams and rivers	maintenance concern				rare visitor; rare/ occasional migrant
short-eared owl	*Asio flammeus*	Grasslands and meadows with some dense vegetation for nesting cover	immediate concern	PE	•		rare visitor (first seen in 2009)

[1] Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2005; McWilliams and Brauning 2000; Peterjohn 2006
[2] Comprehensive Wildlife Conservation Strategy rank (Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2005)
[3] Pennsylvania Biological Survey recommended state legal status: **CA** = candidate at risk; **CR** = candidate rare; **CU** = conditioned undetermined; **PE** = endangered; **PT** = threatened (Pennsylvania Natural Heritage Program 2010c)
[4] Partners in Flight 2008; Panjabi et al. 2005
[5] **Breeder** = confirmed nesting; **migrant** = rests and feeds in transit in spring/fall; **winter resident** = rests and feeds in winter; **visitor** = seen intermittently in one or more seasons.

common name	taxon	specific habitat requirements[1]	CWCS rank[2]	PABS status[3]	grassland-interior species[1]	Partners in Flight status and regional priority level[4]	recent VAFO status[5]
long-eared owl	*Asio otus*	Conifer woods intermingled with fields and meadows	high-level concern	CU			rare migrant
barn owl	*Tyto alba*	Meadows and old fields with nearby nesting cavities	maintenance concern	CR	•		rare visitor, migrant & winter resident
common nighthawk	*Chordeiles minor*	Expanses of gravel (often rooftops)	maintenance concern				rare migrant
willow flycatcher	*Empidonax traillii*	Shrub swamps, wet meadows, shrubby habitats along streams and the edges of ponds and marshes, and dry upland grasslands	maintenance concern			global watch list; 4: planning and responsibility	rare migrant
eastern kingbird	*Tyrannus tyrannus*	Grasslands and fields with scattered trees or hedgerows				3: management attention	common breeder; common/ uncommon migrant
loggerhead shrike	*Lanius ludovicianus*	Short grasses and forbs interspersed with patches of bare ground and shrubs or small trees	immediate concern	PE	•	3: management attention	not seen
horned lark	*Eremophila alpestris*	Large-scale grasslands with short grasses and forbs and patches of bare ground			•		rare migrant
brown thrasher	*Toxostoma rufum*	Overgrown fields and forest edges with a mosaic of open grasslands or meadows, shrub thickets, and scattered trees	maintenance concern			regional stewardship responsibility; 4: planning and responsibility	uncommon breeder & migrant; rare winter resident

(Table continued on next page.)

[1,2,3,4,5] See footnotes on p. 52.

common name	taxon	specific habitat requirements[1]	CWCS rank[2]	PABS status[3]	grassland-interior species[1]	Partners in Flight status and regional priority level[4]	recent VAFO status[5]
sedge wren	*Cistothorus platensis*	Densely vegetated wet meadows and old fields	immediate concern	PE	•	2: immediate management	not seen
prairie warbler	*Dendroica discolor*	Grasslands and thickets with scattered or patchy small conifers	maintenance concern			global watch list; regional stewardship responsibility; 3: management attention	occasional breeder; rare/ occasional migrant
yellow-breasted chat	*Icteria virens*	Low, dense shrub thickets with an open or partially open tree canopy	maintenance concern				rare visitor & migrant
blue-winged warbler	*Vermivora pinus*	Herbaceous openings, thickets and early successional forests	maintenance concern; Pennsylvania responsibility			global watch list; 3: management attention	uncommon breeder & migrant
Henslow's sparrow	*Ammodramus henslowii*	Large-scale grasslands with dense ground litter and little or no bare ground or shrubs	high-level concern; Pennsylvania responsibility		•	global watch list; 1: critical recovery	not seen
grasshopper sparrow	*Ammodramus savannarum*	Large-scale grasslands with short grasses and forbs, dense ground litter, patches of bare ground, and scattered shrubs	maintenance concern		•	3: management attention	rare visitor; rare migrant
savannah sparrow	*Passerculus sandwichensis*	Upland grasslands and grassy fallow fields with patchy short grasses and forbs			•		occasional migrant
eastern towhee	*Pipilo erythrophthalmus*	Thickets, hedgerows, woodland edges, shrubby fields and dense understories of open-canopied woodlands				regional stewardship responsibility; 3: management attention	common breeder & migrant; rare winter resident

common name	taxon	specific habitat requirements[1]	CWCS rank[2]	PABS status[3]	grassland-interior species[1]	Partners in Flight status and regional priority level[4]	recent VAFO status[5]
vesper sparrow	*Pooecetes gramineus*	Extensive upland grasslands with short grasses and forbs, patches of bare soil, and widely scattered trees or shrubs			•		rare visitor
field sparrow	*Spizella pusilla*	Overgrown old fields with low shrubs and small trees	[drastic decline]			regional stewardship responsibility; 3: management attention	uncommon breeder & migrant; occasional winter resident
blue grosbeak	*Passerina caerulea*	Grasslands with shrub patches or scattered trees and along woodland edges and shrubby fencerows				regional stewardship responsibility; 4: planning and responsibility	rare visitor & migrant
indigo bunting	*Passerina cyanea*	Woodland edges, shrubby fields, thickets and young woodlands with clearings				4: planning and responsibility	common breeder; common/ uncommon migrant
dicksissel	*Spiza americana*	Old fields and grasslands with intermediate to tall vegetation and moderate ground litter	high-level concern	PE	•		extremely rare migrant
bobolink	*Dolichonyx oryzivorus*	Moist meadows, fields and grasslands of tall grasses and forbs, with dense ground litter	maintenance concern		•		occasional breeder; rare/ occasional migrant
eastern meadowlark	*Sturnella magna*	Grasslands and fallow fields of tall grasses and forbs, with dense ground litter and sparse trees	maintenance concern		•	3: management attention	common breeder; common/ uncommon migrant; uncommon winter resident

[1,2,3,4,5] See footnotes on p. 52.

Table 20. **Mammals, turtles, snakes, lizards and amphibians of special conservation concern recently confirmed in or potentially inhabiting grasslands and meadows in Valley Forge National Historical Park** (Hulse et al. 2001; Kirkland and Hart 1999; Tiebout 2003; Yahner et al. 2001; Yahner et al. 2006)

common name	taxon	specific habitat requirements[1]	CWCS rank[2]	PABS status[3]	recent VAFO status
MAMMALS					
least shrew	*Cryptotis parva*	Densely vegetated grasslands and old fields near water	high-level concern	PE	not seen
southern bog lemming	*Synaptomys cooperi*	Old fields, mixed deciduous-coniferous woodlands, and margins of wetlands	maintenance concern		not seen
TURTLES					
eastern box turtle	*Terrapene carolina*	Deciduous forests, old fields, forest-meadow edges and marshy areas	maintenance concern		uncommon; mainly in forest habitats
SNAKES AND LIZARDS					
eastern hognose snake	*Heterodon platirhinos*	Sandy grasslands and forest clearings, often in floodplains	maintenance concern		not seen
shorthead garter snake	*Thamnophis brachystoma*	Riparian old fields and meadows with grasses, sedges and low forbs	high-level concern; Pennsylvania responsibility		not seen
eastern ribbon snake	*Thamnophis sauritus sauritus*	Edges of marshes, streams, rivers, ponds and lakes with dense sedges, grasses, rushes and emergent shrubs, and abundant frogs	high-level concern		not seen
eastern fence lizard	*Sceloporus undulatus*	Grasslands and old fields adjacent to deciduous forest, and open rock faces and talus in forests	maintenance concern		not seen

[1] Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2005
[2] **CWCS** = Comprehensive Wildlife Conservation Strategy (Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2005)
[3] Pennsylvania Biological Survey recommended state legal status: **PE** = endangered (Pennsylvania Natural Heritage Program 2010c)

common name	taxon	specific habitat requirements[1]	CWCS rank[2]	PABS status[3]	recent VAFO status
AMPHIBIANS					
Fowler's toad	*Bufo fowleri*	River floodplains, lake edges, and grasslands with alluvial gravel and sand	maintenance concern		uncommon; north of Schuylkill River only
New Jersey chorus frog	*Pseudacris triseriata kalmi*	Permanently or seasonally inundated swamps, marshes, wet meadows, floodplains and riparian corridors	high-level concern	PE	not seen
northern leopard frog	*Rana pipiens*	Seasonal pools and wet meadows for breeding, with adjacent grasslands or old fields for foraging	maintenance concern		documented historically; rare if present
coastal plain leopard frog	*Rana sphenocephala*	Marshes, ponds, wet meadows, and the edges of slow-moving rivers and streams	Pennsylvania vulnerable	PE	not seen
eastern spadefoot	*Scaphiopus holbrookii*	Seasonal pools in meadows and woodlands with sandy to loamy soils	high-level concern	PE	documented historically; rare if present

[1,2,3] See footnotes on p. 56.

Table 21. **Butterflies of special conservation concern recently confirmed in or potentially inhabiting grasslands and meadows in Valley Forge National Historical Park** (Ruffin 1994; Anonymous 1996; Wright 2007; Pennsylvania Natural Heritage Program 2010a; B. Leppo, personal communication). Other butterfly species confirmed or potentially present in Valley Forge National Historical Park are listed in Appendix G (p. 257).

taxon	common name	larval host plants or prey[1]	global rank[2]	state rank[2]	local occurrence[3]
Hesperiidae (skippers)					
Amblyscirtes vialis	common roadside skipper	Poaceae	G5	S2S4	county
Atrytonopsis hianna	dusted skipper	*Andropogon, Schizachyrium*	G4G5	S2S3	county
Autochton cellus	golden-banded skipper	*Amphicarpaea bracteata*	G4	SH	county
Erynnis lucilius	columbine duskywing	*Aquilegia canadensis*	G4	S1S3	county
Erynnis martialis	mottled duskywing	*Ceanothus americanus*	G3G4	SH	park
Euphyes bimacula	two-spotted skipper	*Carex*	G4	S2S3	county
Euphyes dion	Dion skipper	*Carex*	G4	S1	ecoregion
Hesperia leonardus	Leonard's skipper	Poaceae	G4	S3S4	park
Hesperia metea	cobweb skipper	*Andropogon, Schizachyrium*	G4G5	S2S3	park
Hesperia sassacus	Indian skipper	Poaceae	G5	S3S4	county
Nastra lherminier	swarthy skipper	*Schizachyrium*	G5	S2S3	park
Poanes massasoit	mulberry wing	*Carex*	G4	S3	park
Polites mystic	long dash	Poaceae	G5	S3	park
Thorybes bathyllus	southern cloudywing	*Lespedeza* and other Fabaceae	G5	S3S4	park
Lycaenidae (harvesters, coppers, hairstreaks, blues)					
Callophrys augustinus	brown elfin	*Vaccinium, Kalmia*	G5	S3S4	park
Callophrys gryneus	juniper hairstreak	*Juniperus virginiana*	G5	S2S4	park
Callophrys henrici	Henry's elfin	*Cercis canadensis, Ilex opaca, Vaccinium*	G5	S1S3	park
Callophrys irus	frosted elfin	*Baptisia tinctoria, Lupinus perennis*	G3	S1S2	park

[1] B. Leppo, personal communication (compiled from many sources for Pennsylvania Natural Heritage Program)
[2] See explanation of global and state rarity ranks at end of table.
[3] Smallest confirmed area of local occurrence: **park** = within VAFO; **county** = within Chester or Montgomery Counties; **ecoregion** = in Greater Piedmont

taxon	common name	larval host plants or prey[1]	global rank[2]	state rank[2]	local occurrence[3]
Callophrys niphon	eastern pine elfin	*Pinus rigida, P. strobus*	G5	S3	park
Callophrys polios	hoary elfin	*Epigaea repens*	G5	SH	ecoregion
Celastrina neglectamajor	Appalachian azure	*Actaea racemosa*	G4	S3S4	county
Lycaena hyllus	bronze copper	*Rumex*	G5	SU	county
Parrhasius m-album	white M hairstreak	*Quercus*	G5	S3S4	park
Satyrium edwardsii	Edwards' hairstreak	*Quercus ilicifolia,* occasionally *Q. velutina*	G4	S3S4	county
Satyrium titus	coral hairstreak	*Prunus*	G5	S3S4	park
Nymphalidae (snouts, heliconians, fritillaries, brush-foots, admirals, emperors, satyrs, monarchs)					
Asterocampa clyton	tawny emperor	*Celtis*	G5	S3S4	park
Chlosyne nycteis	silvery checkerspot	*Helianthus* and other Asteraceae	G5	S3S4	park
Enodia anthedon	northern pearly eye	Poaceae	G5	S3S4	park
Euphydryas phaeton	Baltimore	Chelone, Agalinis, Aureolaria, Plantago; later instars also Lonicera, Pedicularis, Viburnum	G4	S2S4	county
Phyciodes cocyta	northern crescent	*Symphyotrichum*	G5	S3S4	ecoregion
Polygonia progne	gray comma	*Ribes*	G5	SU	county
Satyrodes eurydice	eyed brown	*Carex*	G4	S1S3	county
Speyeria aphrodite	Aphrodite fritillary	*Viola*	G5	S3S4	county
Speyeria atlantis	Atlantis fritillary	*Viola*	G5	SU	ecoregion
Speyeria idalia	regal fritillary	*Viola*	G3	S1	county
Papilionidae (swallowtails)					
Eurytides marcellus	zebra swallowtail	*Asimina triloba*	G5	S3S4	county
Papilio cresphontes	giant swallowtail	*Zanthoxylum americanum, Ptelea trifoliata*	G5	S2	county
Pieridae (whites and sulphurs)					
Anthocharis midea	falcate orangetip	Apiaceae, mainly *Arabis, Cardamine*	G4G5	S3	county
Pieris virginiensis	West Virginia white	*Cardamine concatenata, C. diphylla*	G3	S2S3	ecoregion
Pontia protodice	checkered white	*Lepidium* and other Apiaceae	G4	SH	county
Riodinidae (metalmarks)					
Calephelis borealis	northern metalmark	*Packera obovata*	G3G4	S1S2	county

Table 21 (continued)

Explanation of global and state rarity ranks

G3	Vulnerable globally because very rare and local throughout its range, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extinction. Typically 21–100 occurrences or 3,000–10,000 individuals in the species' total range.
G4	Uncommon but not rare globally, and usually widespread. Possibly cause for long-term concern. Typically more than 100 occurrences and more than 10,000 individuals in the species' total range.
G5	Secure globally. Common, typically widespread and abundant, with considerably more than 100 occurrences and 10,000 individuals in the species' total range.
G#G#	Numeric range (e.g., G3G4) used to indicate uncertainty about global status. More information is needed.
S1	Critically imperiled in the state because of extreme rarity or because of some factor(s) making it extremely vulnerable to extirpation from the state. Typically 5 or fewer occurrences or very few remaining individuals or acres within the state.
S2	Imperiled in the state because of rarity or because of some factor(s) making it very vulnerable to extirpation from the state. Typically 6–20 occurrences or few remaining individuals or acres within the state.
S3	Vulnerable in the state because rare, or found only in a restricted range (even if abundant at some locations), or because of other factors making it vulnerable to extirpation. Typically 21–100 occurrences within the state.
S4	Uncommon but not rare, and usually widespread in the state. Apparently secure. Usually more than 100 occurrences within the state.
S#S#	Numeric range (e.g., S2S3) used to indicate uncertainty about status in the state. More information is needed.
SH	Occurred historically in the state, not verified in the past 20 years but suspected to be still extant. A rank of SH applies without a 20-year delay after the most recent documented occurrence if the only known occurrences in the state were destroyed or subjected to intensive searching but not found. A rank of SH typically changes to S1 upon verification of an extant occurrence.
SU	Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.

4.5 Extant Reference Sites in the Greater Piedmont

The present-day inventory consists of 45 reference sites dominated by native grassland/meadow specialist plants (Table 22), 31 in the Greater Piedmont and 14 in portions of adjacent ecoregions where nearly all of the native grassland/meadow species are also indigenous to the Greater Piedmont. Serpentine grasslands and diabase meadows are included, even though their signature bedrock types are not present in VAFO, because many of the species living in them also have a significant presence in the region's other grassland and meadow communities. About 15 plant species are narrowly restricted to serpentine grasslands, enough to make them outliers in a DCA analysis of long-lived grassland/meadow remnants across Pennsylvania; those species are omitted from the potential flora of VAFO grasslands and meadows. With their high diversity and relative intactness the 45 reference sites serve as exemplary models for reclamation and are among the richest potential sources of local genotypes in the region for introduction or reintroduction of grassland/meadow species of plants (see Table 24, p. 66) and animals.

Few of the reference sites have plant species inventories conducted at levels of search intensity comparable to recent surveys of VAFO grasslands and meadows. Those for which recent, comprehensive, multi-year surveys exist include three remnants of pre-European-settlement grasslands and meadows at Nottingham Barrens, Unionville Barrens and Fulshaw Craeg Meadows and a large grassland maintained by human disturbance for the past 70 years at Fort Indiantown Gap.

In VAFO's 541 ha (1,340 acres) of grasslands and meadows, 172 native grassland/meadow species and 141 nonnative species were confirmed present in 1991–2007 (Appendix C, pp. 153-206). Corresponding tallies at the four well-surveyed reference sites are shown in Table 23 (pp. 63-64) and Figure 12 (p. 65). Relative to the total area in

(continued on p. 65)

Table 22. **Extant reference sites of unplanted, long-established, high-diversity native grasslands and meadows** in the Greater Piedmont and elsewhere in eastern Pennsylvania. List is not exhaustive.

site	county(ies)	principal managing entity
SERPENTINE GRASSLANDS		
Brintons Quarry	Chester	Quarry Swimming Association
Chrome Barrens	Chester	The Nature Conservancy; partly private
Fern Hill	Chester	private
Marshallton Barrens	Chester	Natural Lands Trust
New Texas Barrens	Lancaster	Lancaster County Conservancy
Nottingham Barrens	Chester	Chester County Department of Parks and Recreation
Pink Hill	Delaware	John J. Tyler Arboretum
Rock Springs Barrens	Lancaster	Lancaster County Conservancy
Sugartown Barrens	Chester	Natural Lands Trust
Unionville Barrens	Chester	Natural Lands Trust; partly private
DIABASE MEADOWS		
Almont Meadow	Bucks	private
Argus Meadow	Bucks	Pennsylvania Game Commission
Boutcher Road Meadow	Montgomery	private (in a powerline right-of-way)
Camp Shand Meadow	Lancaster, Lebanon	private (in a powerline right-of-way)
Cat Hill Road Meadow	Bucks	private (in a powerline right-of-way)
Covered Bridge Meadow	Bucks	private
Fulshaw Craeg Meadows	Montgomery	Natural Lands Trust
Gifford Pinchot State Park Meadow	York	Pennsylvania Bureau of State Parks
Lonely Road Meadow	Bucks	private
Pardee Field	Adams	National Park Service
Revere Meadow	Bucks	Pennsylvania Game Commission

(Table continued on next page.)

site	county(ies)	principal managing entity
Powers Hill Meadow	Adams	National Park Service
Schneider Family Meadows	York	private
The Wheatfield	Adams	National Park Service
SANDY COASTAL PLAIN MEADOWS		
Bristol Meadow	Bucks	private
Delhaas Woods Meadow	Bucks	Bucks County Department of Parks and Recreation
Johnsons Corner Grassland	Delaware	private
Neshaminy State Park Meadows	Bucks	Pennsylvania Bureau of State Parks
Rohm and Haas Meadow	Bucks	private
XERIC LIMESTONE PRAIRIES		
Baker Caverns Prairie	Franklin	private
Big Hollow Prairie*	Centre	Pennsylvania State University
Canoe Creek Prairie*	Blair	Pennsylvania Bureau of State Parks
Eiswert Limestone Prairie*	Lycoming	private
Great Plains*	Centre	private
Kurtz Valley Ridge Prairie*	Juniata	private
McAlisterville Ridge Rock*	Juniata	private
Missionary Prairie*	Snyder	private
Tytoona Cave Prairie*	Blair	private
Westfall Ridge Prairie*	Juniata	The Nature Conservancy; partly private
RIVERINE GRASSLANDS AND MEADOWS		
Byers Island*	Northumberland	unknown
Clarks Island*	Columbia	unknown
French Island*	Columbia	unknown
Menches Island*	Columbia, Montour	unknown
Shapnack Island*	Pike	National Park Service
Susquehanna Lock 12 Meadows	York	PPL Corporation
MESIC LIMESTONE MEADOWS		
Atglen Meadow	Chester	private
MISCELLANEOUS PIEDMONT NATIVE GRASSLANDS AND MEADOWS		
Huston Meadow	Philadelphia	Philadelphia Department of Parks and Recreation
Haverford Reserve Meadow	Delaware	Haverford Township Department of Parks and Recreation
PERSISTENT NATIVE GRASSLANDS OF MORE RECENT ORIGIN		
Fort Indiantown Gap military training corridor	Dauphin, Lebanon	Pennsylvania Department of Military and Veterans Affairs

* Site in another, nearby ecoregion

Table 23. **Comparison of grassland/meadow floras at Valley Forge National Historical Park and four reference sites**. *Native grassland/ meadow specialists* and *nonnatives* refer to vascular plant species. The reference sites are in the Greater Piedmont, roughly 25, 30, 65 and 110 km (in order of appearance in the table) from Valley Forge.

surveyed site	grassland/ meadow area in ha (acres)	native grassland/ meadow specialists (% of total species)	nonnatives in grasslands/ meadows (% of total species)	total species richness	most frequently dominant species (nonnatives marked with "I" for introduced)	survey years	source(s)
Valley Forge National Historical Park grasslands and meadows	531 (1,340)	172 (48%)	141 (39%)	361	*Andropogon virginicus* *Anthoxanthum odoratum* (I) *Festuca rubra* (I) *Lonicera japonica* (I) *Microstegium vimineum* (I) *Poa pratensis* (I) *Schedonorus pratensis* (I)	1991–2007	see Appendix C, pp. 153-206
Fulshaw Craeg Preserve meadows	1.5 (3.7)	156 (55%)	53 (19%)	283	*Anthoxanthum odoratum* (I) *Desmodium paniculatum* *Fragaria virginiana* *Microstegium vimineum* (I) *Pycnanthemum tenuifolium* *Solidago altissima* *Solidago gigantea* *Solidago juncea* *Solidago nemoralis* *Solidago rugosa* *Sorghastrum nutans*	1981–2009	R. E. Latham (unpublished)
Unionville Barrens grasslands	3.5 (8.5)	98 (59%)	23 (14%)	165	*Aristida dichotoma* *Aristida purpurascens* *Bouteloua curtipendula* *Quercus stellata* *Schizachyrium scoparium* *Smilax rotundifolia* *Sorghastrum nutans*	2002–2010	Latham (2005b); R. E. Latham (unpublished)

(Table continued on next page.)

surveyed site	grassland/ meadow area in ha (acres)	native grassland/ meadow specialists (% of total species)	nonnatives in grasslands/ meadows (% of total species)	total species richness	most frequently dominant species (nonnatives marked with "I" for introduced)	survey years	source(s)
Nottingham Barrens grasslands	32 (79)	178 (61%)	58 (20%)	291	*Andropogon gerardii* *Aristida dichotoma* *Pinus rigida* *Quercus marilandica* *Quercus stellata* *Schizachyrium scoparius* *Smilax rotundifolia* *Smilax rotundifolia* *Sorghastrum nutans* *Sporobolus heterolepis* *Symphyotrichum depauperatum*	1996–2004	R. E. Latham, J. Ebert and J. Holt (unpublished)
Fort Indiantown Gap military training corridor grasslands	1,100 (2,800)	338 (59%)	170 (29%)	577	*Andropogon virginicus* *Centaurea stoebe* ssp. *micranthus* (I) *Comptonia peregrina* *Dichanthelium clandestinum* *Rubus flagellaris* *Schizachyrium scoparium* *Solidago gigantea* *Solidago juncea* *Solidago rugosa*	1994–2008	Latham et al. (2007b); Pennsylvania National Guard (2009)

grasslands and meadows, the number of nonnative species at VAFO is consistent with the four reference sites, whereas the number of native grassland/ meadow species is low (Figure 12). How much VAFO departs from the pattern set by the four reference sites can be approximated using log-linear regressions of area vs. species richness as predictive models. If VAFO were consistent with the other sites, the predicted number of native grassland/meadow species would be 285, or 66% higher than the actual number; using the same method, the predicted nonnative species count is within 7% of the actual value.

More important than how many species are present in the two categories is their relative population abundance. At the reference sites, nearly all of the species that are most often dominant or co-dominant in survey plots are native grassland/meadow species; nonnative species are subordinate or rare. At VAFO, nonnatives dominate most often and native grassland/meadow species are scattered or patchy (Table 12, p. 36).

Of the reference sites, two have had plant species cover surveyed using methods similar to the recent survey of VAFO grasslands and meadows (Furedi 2008)—Nottingham Barrens (NB) and the Fort Indiantown Gap training corridor (FIG)—although sampling intensity was much lower in those studies. Using the aggregate area covered by all study plots as a proxy, sampling intensity in the VAFO grassland/meadow plots was roughly 10 and 100 times that of the survey plots at FIG and NB, respectively (Table 25, pp. 67-69). Between-site comparisons should be viewed with that caveat in mind. Some statistics, such as species richness, are likely to be appreciably skewed by sampling intensity, causing richness values for NB and FIG to be artificially lowered compared with those for VAFO. Others, such as species evenness and between-plot species turnover, are expected to be less sensitive.

Overall habitat size is another factor that may muddle comparisons. Species richness and between-plot species turnover (patch diversity) generally increase with area, so two sites with similar values in either of those variables but very different areas of land in grassland/meadow habitat may not be as similar as the numbers would suggest. For instance, surveys at FIG and NB show similar

(continued on p. 69)

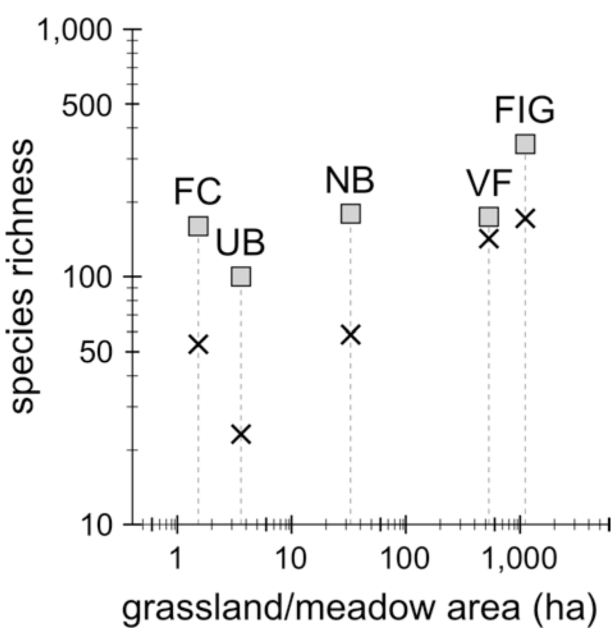

Figure 12. **Comparison of total species richness of native grassland/meadow plants (squares) and nonnative plants (×s) in Valley Forge National Historical Park and four reference sites.** FC = Fulshaw Craeg Preserve meadows; FIG = Fort Indiantown Gap military training corridor grasslands; NB = Nottingham Barrens grasslands; UB = Unionville Barrens grasslands; VF = Valley Forge National Historical Park grasslands and meadows. (See Table 23, pp. 63-64, for further details and data sources.

Table 24. **Native herbaceous species from the present and historical flora of Valley Forge with a frequency "deficit" in the park's grasslands and meadows.** These are perennials and biennials with frequencies in grassland and meadow survey plots (Furedi 2008) of more than 20 (up to 46.5) percentage points below their frequencies among historical reference sites in the Greater Piedmont and nearby.

MAINLY MESIC SITES:

autumn bentgrass (*Agrostis perennans*)
big bluestem (*Andropogon gerardii*)
crested sedge (*Carex cristatella*)
blue sedge (*C. glaucodea*)
greater straw sedge (*C. normalis*)
broom sedge (*C. scoparia*)
devil's-bit (*Chamaelirium luteum*)
yellow nutsedge (*Cyperus esculentus*)
Bosc's panic-grass (*Dichanthelium boscii*)
deer-tongue (*D. clandestinum*)
riverbank wild-rye (*Elymus riparius*)
Virginia wild-rye (*E. virginicus*)
field horsetail (*Equisetum arvense*)
hollow-stemmed joe-pye-weed (*Eutrochium fistulosum*)
sweet-scented joe-pye-weed (*E. purpureum*)
wild strawberry (*Fragaria virginiana*)
thinleaf sunflower (*Helianthus decapetalus*)
ox-eye (*Heliopsis helianthoides*)
bluets (*Houstonia caerulea*)
dwarf St. John's-wort (*Hypericum mutilum*)
spotted St. John's-wort (*H. punctatum*)
yellow star-grass (*Hypoxis hirsuta*)
dwarf dandelion (*Krigia biflora*)
fringed loosestrife (*Lysimachia ciliata*)
field mint (*Mentha arvensis*)
wirestem muhly (*Muhlenbergia frondosa*)
little evening primrose (*Oenothera perennis*)
switchgrass (*Panicum virgatum*)
tall white beard-tongue (*Penstemon digitalis*)
clammy ground-cherry (*Physalis heterophylla*)
longleaf ground-cherry (*P. subglabrata*)
northern bracken fern (*Pteridium aquilinum*)
hoary mountain-mint (*Pycnanthemum incanum*)
narrowleaf mountain-mint (*P. tenuifolium*)
Virginia mountain-mint (*P. virginianum*)
hyssop skullcap (*Scutellaria integrifolia*)
northern wild senna (*Senna hebecarpa*)
starry campion (*Silene stellata*)
smooth goldenrod (*Solidago gigantea*)
early goldenrod (*S. juncea*)
pencil-flower (*Stylosanthes biflora*)
panicled aster (*Symphyotrichum lanceolatum*)
calico aster (*S. lateriflorum*)
New England aster (*S. novae-angliae*)
late purple aster (*Symphyotrichum patens*)
wild germander (*Teucrium canadense*)

MAINLY DRIER SITES:

pearly everlasting (*Anaphalis margaritacea*)
overlooked pussytoes (*Antennaria neglecta*)
butterfly-weed (*Asclepias tuberosa*)
green milkweed (*A. viridiflora*)
field thistle (*Cirsium discolor*)
Great Plains flatsedge (*Cyperus lupulinus*)
poverty panic-grass (*Dichanthelium depauperatum*)
slimleaf witchgrass (*D. linearifolium*)
robin's-plantain (*Erigeron pulchellus*)
slender bush-clover (*Lespedeza virginica*)
horsemint (*Monarda fistulosa*)
northeastern beard-tongue (*Penstemon hirsutus*)
black-eyed-susan (*Rudbeckia hirta* var. *pulcherrima*)
lyreleaf sage (*Salvia lyrata*)
Indian-grass (*Sorghastrum nutans*)
wedgegrass (*Sphenopholis nitida*)
clasping heartleaf aster (*Symphyotrichum undulatum*)

MAINLY WETTER SITES:

marsh bellflower (*Campanula aparinoides*)
lurid sedge (*Carex lurida*)
fox sedge (*C. vulpinoidea*)
slender spike-rush (*Eleocharis tenuis* var. *tenuis*)
boneset (*Eupatorium perfoliatum*)
sharp-fruited rush (*Juncus acuminatus*)
rice cutgrass (*Leersia oryzoides*)
American water horehound (*Lycopus americanus*)
northern bugleweed (*L. uniflorus*)
Allegheny monkey-flower (*Mimulus ringens*)
redtop panic-grass (*Panicum rigidulum*)
Georgia bulrush (*Scirpus georgianus*)
mad-dog skullcap (*Scutellaria lateriflora*)
creeping hedge-nettle (*Stachys tenuifolia*)
purple-stemmed aster (*Symphyotrichum puniceum*)
tall meadow-rue (*Thalictrum pubescens*)
blue vervain (*Verbena hastata*)
New York ironweed (*Vernonia noveboracensis*)

Table 25. **Comparison of quantitative species cover data at Valley Forge National Historical Park (VAFO), Fort Indiantown Gap training corridor (FIG) and Nottingham Barrens (NB)**. Richness values differ from those in Tables 11 and 12 (pp. 34, 36) because in this table they include only plants recorded in quantitative survey plots (see *Methods*, p. 24). Data for VAFO are from Furedi (2008), for FIG, from The Nature Conservancy (2000) and for NB, from R. E. Latham, J. Ebert and J. Holt (unpublished). The difference between the total species count and the sum of native grassland/meadow species plus nonnatives consists of native species that are not grassland/meadow specialists and taxa whose origins are ambiguous because specimens lacked flowers, fruits or other key characters and could be identified only to the genus or family level, in taxa that include both native and nonnative species.

quantity compared		VAFO	FIG	NB
SITE AND SURVEY CHARACTERISTICS				
total grassland/meadow area at site	ha (acres)	531 (1,340)	1,100 (2,800)	32 (79)
size of each sampling plot	m^2 (sq. ft.)	25 (269)	25 (269)	1 (10.8)
number of sampling plots		175	18	33
total area of sampling plots	m^2 (sq. ft.)	4,375 (47,092)	450 (4,844)	33 (355)
relative sampling intensity (as percent of total plot area at VAFO)		100	10.3	0.8
SPECIES DIVERSITY				
species richness across all plots (γ)	all species	238	116	87
	grassland/meadow species	93	66	65
	nonnatives	98	33	8
average species richness per plot (α)	all species	23.2	24.2	11.0
	grassland/meadow species	8.5	16.0	9.7
	nonnatives	11.9	6.7	0.2
range (minimum–maximum) of species richness per plot	all species	9–39	12–37	5–19
	grassland/meadow species	0–18	8–25	3–17
	nonnatives	3–23	0–15	0–1
upper quartile of species richness per plot	all species	28	31	14
	grassland/meadow species	11	18	11
	nonnatives	14	9	0
average percent of all species in plot	grassland/meadow species	36	67	88
	nonnatives	52	26	2
range (minimum–maximum) of percent of all species in plot	grassland/meadow species	0–67	52–92	50–100
	nonnatives	22–80	0–47	0–12
average percent of total plot cover	grassland/meadow species	28	78	94
	nonnatives	68	17	0.5

(Table continued on next page.)

quantity compared		VAFO	FIG	NB
range (minimum–maximum) of percent of total plot cover	grassland/meadow species	0–85	12–100	59–100
	nonnatives	14–99	0–88	0–7.6
average species evenness per plot ($E_{1/D}$; scale: 0–100)		24.8	19.2	30.8
range (minimum–maximum) of species evenness per plot		7.1–52.3	8.8–38.6	14.3–58.8
upper quartile of species evenness per plot		31.6	25.2	34.9
PATCH DIVERSITY IN SPECIES COMPOSITION				
species turnover among plots (β_H; scale: 0–100)		2.9	12.7	11.2
percent of plots with > 50% cover of native perennial grasses		6.9	38.2	78.8
average species richness of native perennial grasses in those plots		5.4	3.3	4.1
range (minimum–maximum) of species richness of native perennial grasses in those plots		2 – 8	2 – 5	2 – 8
percent of plots with > 50% cover of native grassland/meadow forbs		3.4	27.5	3.0
average species richness of native grassland/meadow forbs in those plots		7.7	11.3	2.0
range (minimum–maximum) of species richness of native grassland/meadow forbs in those plots		5 – 11	9 – 15	2
COMMUNITY PHYSICAL STRUCTURE				
average herbaceous native grassland/meadow species relative height per plot, weighted by percent cover*		3.46	2.89	2.76
range (minimum–maximum) of herbaceous native grassland/ meadow species relative height per plot*		2.00–4.00	2.07–3.94	1.17–4.26
lower quartile of herbaceous native grassland/meadow species relative height per plot*		3.22	2.66	2.22
upper quartile of herbaceous native grassland/meadow species relative height per plot*		3.83	2.93	3.09
average total plant species cover per plot (index of vegetation density)		194	77	128
range (minimum–maximum) of total plant species cover per plot		75–422	31–127	77–195
lower quartile of total plant species cover per plot		146	65	115
upper quartile of total plant species cover per plot		240	100	141

* See definitions of relative height classes at end of table.

quantity compared	VAFO	FIG	NB
percent of plots with total plant species cover less than 100% (index of bare ground coverage)	0.03	77.8	15.2
average difference between total plant species cover and 100% in those plots (index of bare ground coverage)	10.3	35.7	9.2
average native grassland/meadow shrub or small tree species cover per plot	5.6	2.8	5.7
percent of plots with 0% native grassland/meadow shrub or small tree species cover (species listed in Appendices D and E)	92.0	83.3	39.4
percent of plots with 0.1%–10% native grassland/meadow shrub or small tree species cover	6.3	5.6	48.5
percent of plots with 10.1%–25% native grassland/meadow shrub or small tree species cover	0.6	5.6	6.1
percent of plots with > 25% native grassland/meadow shrub or small tree species cover	1.1	5.6	6.1
KEY BUTTERFLY HABITAT PLANT SPECIES			
frequency (percent of plots where present) of violet cover (10 *Viola* taxa listed in Appendix D)	21.7	33.3	6.0
average violet cover per plot where present	0.49	0.67	1.0
frequency (percent of plots where present) of native thistle cover (5 *Cirsium* taxa listed in Appendices D and E)	9.1	5.6	3.0
average native thistle cover per plot where present	2.81	0.50	1.0
frequency (percent of plots where present) of milkweed cover (10 *Asclepias* taxa listed in Appendices D and E)	42.9	38.9	3.0
average milkweed cover per plot where present	8.97	3.64	0.17

* Relative height classes of grassland/meadow plant species (typical maximum height under favorable growing conditions):

	cm	feet
1	< 50	< 1½
2	50–90	1½ –3
3	100–160	3½–5
4	170–250	6–8
5	≥ 260	9–10+

species turnover among plots—12.7 and 11.2 on a 0–100 scale—but the grassland area at FIG is more than 30 times as large as at NB. It is likely (but not certain) that the species turnover would differ substantially between the two landscapes if the grassland/meadow areas were the same size.

The histories of the three sites are very different. NB is believed to have been a shifting mosaic of grassland cover and pine-oak woodlands maintained for thousands of years by Native American burning and the unusual nutrient conditions of serpentine soil (Latham 2003). Grasslands at FIG are a mixture of former agricultural land and recently cleared forestland, used exclusively since the 1930s for infantry, armored-vehicle, artillery and aircraft training—sources of chronic, severe soil disturbance and

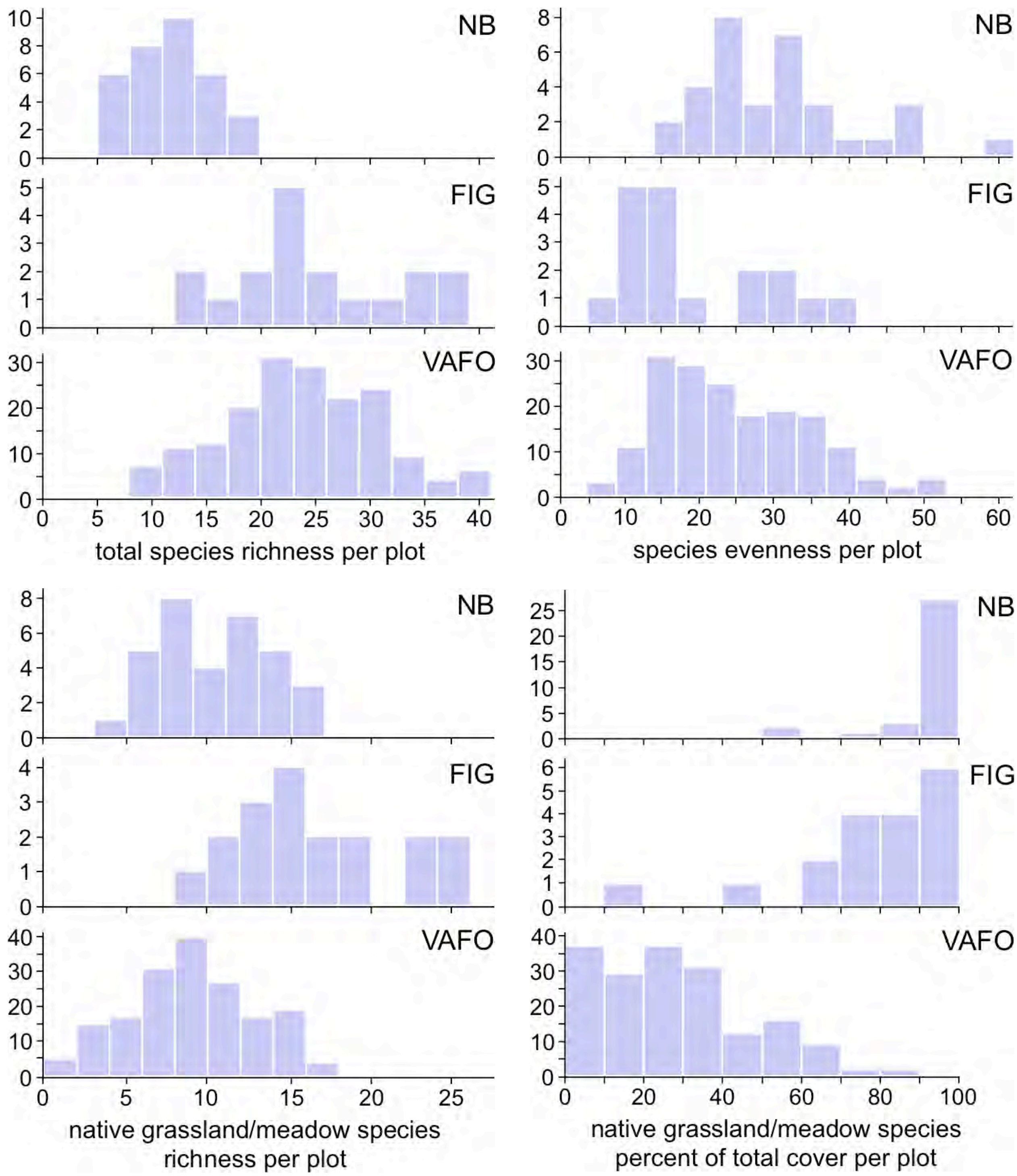

Figure 13. **Frequencies of values related to plant species diversity among grassland/meadow quantitative sampling plots in Nottingham Barrens (NB), Fort Indiantown Gap training corridor (FIG) and Valley Forge National Historical Park (VAFO)**. Height of bar indicates the number of sampling plots in its range of values along the x-axis. Richness data should be compared in light of the differences among the sites in sampling intensity and total grassland/meadow area (see Table 25, pp. 67-69, and explanatory text, pp. 65, 69). Native grassland/meadow species are plants native to the Greater Piedmont that live primarily in grassland and meadow habitats.

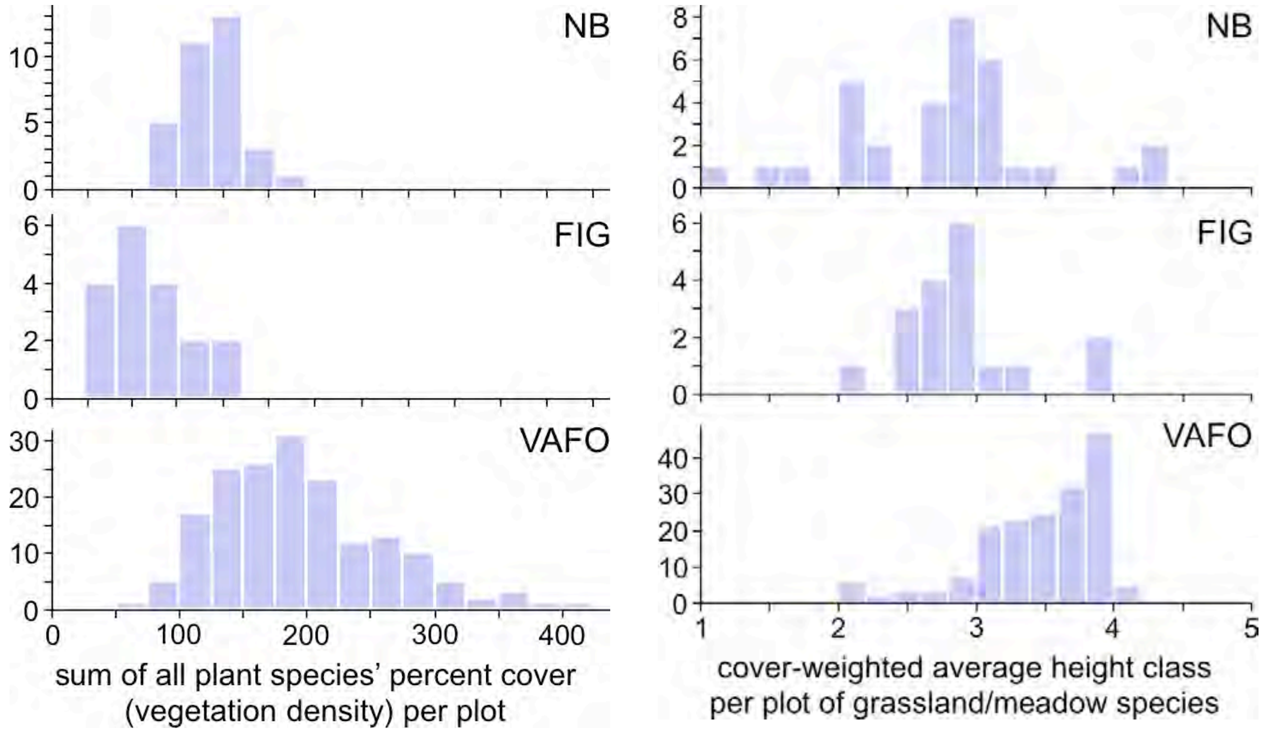

Figure 14. **Frequencies of values related to plant community structure among grassland/ meadow quantitative sampling plots in Nottingham Barrens (NB), Fort Indiantown Gap training corridor (FIG) and Valley Forge National Historical Park (VAFO)**. Height of bar indicates the number of sampling plots in its range of values along the x-axis. Grassland/meadow species are plants native to the Greater Piedmont that live primarily in grassland and meadow habitats.

occasional fires (Latham et al. 2007). VAFO grasslands and meadows were farmed in most areas from around 1700 until 1991, when cultivation was switched to annual or semiannual mowing park-wide.

Average species richness per plot of grassland/meadow species is lowest, and of nonnatives, highest at VAFO (Table 25). The average percentage of species in each plot that are grassland/meadow specialists increases from VAFO to FIG to NB and the percentage that are nonnatives decreases in the same sequence. The percentages of total plant cover follow the same pattern for specialists and nonnatives but the trends are more extreme. Evenness follows a different pattern, with VAFO falling midway between the lowest value at FIG and the highest at NB.

Species turnover among plots (an index of patch diversity) is highest at FIG, slightly lower at NB and much lower at VAFO. Native grassland patches (those with more than 50% cover of native perennial grasses) make up approximately 79% of plots at NB, 38% at FIG, and 7% at VAFO. Native meadow patches (with more than 50% cover of native forbs) comprise roughly 28% of plots at FIG and 3% each at VAFO and NB.

The upper quartile is given for species richness per plot and species evenness per plot (Table 25) as a crude (but easily measured) summary of the data frequency distribution, or more specifically the width of the upper tail of each distribution, where richness and evenness values are high. Upper and lower quartiles are given for herbaceous grassland/meadow species relative height per plot weighted by percent cover (an index of structural diversity among patches) and total plant species cover per plot (an index of vegetation density). The relationships of averages and quartiles to full frequency distributions can be visualized by comparing the histograms in Figures 13 and 14 with the corresponding values in Table 25.

Frequency distributions of survey plots (or patches) are important to the extent that high diversity of patch types is a desired condition. Patch diversity is reflected in the spread and shape of the frequency distributions of the attributes illustrated in Figures 13 and 14. Upper and lower quartiles serve as simplified, easily measured proxies for the distributions' spread and shape; the farther they are from each other or from the average, the wider and flatter the overall distribution.

The histograms showing variation among plots in attributes pertaining to plant community physical structure (Figure 14, previous page) illustrate how quartiles perform as simple indicators of the overall distribution. Vegetation density in VAFO grasslands and meadows appears to be more diverse among patches than at the other two sites. However, a closer look reveals that vegetation density varies from dense (any value > 100%) to extremely dense at VAFO, but it varies from sparse to dense at the other two sites, a more biologically meaningful and advantageous range since some plant, bird and butterfly species of special conservation concern prefer sparsely vegetated habitat. The differences in the distributions are well summarized by comparing quartiles (Table 25). Cover-weighted average height class per plot of native herbaceous grassland/meadow species is spread out most evenly and widely among plots at NB, which has the full gamut of vegetation height with little bias toward one end of the spectrum or the other. By contrast, FIG and especially VAFO are heavily weighted toward patches dominated by tall species.

The shapes of frequency distributions are of little use as metrics to evaluate desired conditions for some of the attributes, for example, percent of total species cover per plot in native grassland/meadow plants (histograms at lower right in Figure 13). In this case, higher is always better and the average alone is an adequate indicator.

4.6 Quaternary Disturbance Regimes

Grasslands and meadows in the Mid-Atlantic Region persist over long time periods only with chronic disturbance. This is true even of those associated with unusual soils, such as serpentine grasslands and maritime sand dune grasslands. Native grassland/meadow species evolved under a particular set of disturbance regimes over the past thousands to millions of years. It is vital to know as much as possible about those regimes in order to make wise decisions about re-creating and sustaining native grassland and meadow communities.

The dependence of grassland on disturbance where forest is the default vegetation is due to succession, or the gradual replacement of one kind of ecological community by another on the same piece of land. The most familiar example of succession in temperate eastern North America is what happens on an abandoned farm field. There is a constant rain everywhere of seeds of many plant species, including trees. Abandoned cropland or pasture usually has a residue of nutrients added in fertilizer or manure, which helps to foster the rapid establishment and growth of seedlings. In early succession, plants of different growth forms—trees, shrubs, grasses and forbs—are all small in stature. In mid-succession, trees and shrubs have grown taller than their herbaceous neighbors. Still later, the trees outstrip the shrubs in height and the plant community becomes a young woodland or forest. When some of the trees have reached full maturity, a forest has entered late succession.

In the absence of disturbance, a transformation occurs in grasslands and meadows, especially along a forest edge. Each year, full-grown forest trees in the region around VAFO deposit 10 to 20 tons or more of dead leaves per acre (J.-L. Machado, personal communication). These leaves decompose and enrich the soil, forming a thick layer of humus. The humus layer is high in nutrients and available moisture and forest plant species concentrate most of their root growth there. This rich, uppermost soil layer also forms beneath the overhanging trees along the grassland edge, making the soil there suitable for colonization by trees, shrubs and invasive plants. Furthermore, the partial shade at the forest edge suppresses the native grassland plants, which are intolerant of shade, while favoring the growth of tree seedlings and other forest species, which are less tolerant of the heat and dry conditions in the middle of a treeless patch of grassland. Disturbances that kill adult trees, remove tree seedlings, or consume or remove dead leaves and other organic matter inhibit soil buildup and succession to forest. It is only with the regular occurrence of such disturbance that grasslands in the Mid-Atlantic Region persist in spite of succession.

Not all paleoecologists agree on how to interpret the various lines of evidence about disturbance regimes prevalent through most of the Quaternary period—roughly the past 2.6 million years—but there is broad consensus on the fundamentals. Most of the contention appears to be about how widespread the effects of grassland and meadow-sustaining disturbances have been in various regions at various times, and not on the mechanics of the disturbances themselves.

In eastern North America, herbaceous communities that follow forest disturbance severe enough to kill all of the trees are short-lived early successional communities. In the year-round moist climate, trees and other forest plants seed in rapidly and reestablish the forest unless disturbance recurs. For grasslands and meadows to persist, disturbance must be frequent enough and severe enough to prevent forest succession from advancing. The natural disturbances sustaining persistent grasslands and meadows in the region historically include fire, grazing and browsing, soil scarification by animals, and flood or ice scour.

What is known about pre-human and pre-European-settlement disturbance regimes is based in large part on stratigraphic palynology—the study of pollen, spores, seeds, charcoal, ash, silica phytoliths and other identifiable decay-resistant particles preserved in layers of peat, soil or wetland sediment whose age can be estimated by various methods. For the latest part of prehistory, data also come from dendrochronology—the study of growth rings and fire scars inside tree trunks. Many inferences are also made by analogy to the dynamics of present-day ecosystems, for instance, comparing the ecosystem effects of mastodons and mammoths with those of elephants.

4.6.1 Pre-human settlement (most of the last 2.6 million years)

For millions of years (with interruptions during the past 2.6 million years by more than a dozen ice ages), grassland- and meadow-sustaining disturbances in all likelihood were mainly the foraging, trampling, bedding down and wallowing activities of large, plant-eating animals. In the Mid-Atlantic Region, woolly mammoth, Columbian mammoth, American mastodon, Wheatley's ground sloth and Jefferson's ground sloth (Cope 1871, 1899; Guilday 1971; Kurtén and Anderson 1980; Williams at al. 1985; Daeschler et al. 1993) shaped ecosystems by killing trees, scarifying and compacting the soil, and starting a cascade of indirect effects (Milchunas et al. 1988; Zimov et al. 1995; Folke et al. 2005) likely leading to a patchwork of persistent grasslands and meadows within a matrix of forest. Like elephants and other large animals today, the North American megafauna were doubtless keystone species or ecosystem engineers, organisms that account for a small share of ecosystem biomass but have a disproportionately powerful influence on ecosystem processes; if such a species is removed or becomes overabundant, profound changes in community composition and structure result.

Herds of large herbivores would have kept some of the areas disturbed by the giant browsers open and in herbaceous cover, just as they do in Africa today where the presence of elephants is associated with the persistence of grasslands even where there is enough rain to support forests (Dublin et al. 1990). In east-central North America those large grazers and browsers were eastern elk, moose, white-tailed deer, American bison (bison may only have occurred west of the Appalachians) and a host of now-extinct species, among them the black bear-sized giant beaver, complex-toothed horse, giant horse, Cope's tapir, vero tapir, long-nosed peccary, Leidy's peccary, flat-headed peccary, fugitive deer and stag-moose (Cope 1871, 1899; Guilday 1971; Kurtén and Anderson 1980; Williams at al. 1985; Daeschler et al. 1993; R. W. Graham, personal communication).

The effects of grazing intensity on grassland diversity depend on climate and the coevolutionary history of the grazers and plants. In non-arid climates grassland diversity generally is low at both very low and high grazing intensities and high at moderately low or intermediate levels (Milchunas et al. 1988). Studies of the effects of bison on grassland plant diversity show that they selectively graze on the competitively dominant grasses while avoiding most forbs and woody species, increasing species diversity by allowing forbs to flourish (Collins et al. 1998). Other studies have shown similar diversity enhancement with moderate grazing by other species, for instance, meadow voles in a restored prairie in Illinois (Howe et al. 2006).

Grazing typically increases patch diversity, as well as species richness, at moderately low or intermediate grazing intensities (de Knegt et al. 2008). Bison and other grazers tend to graze in patches, revisiting the same locations repeatedly, leaving a mosaic of grazed and ungrazed areas. Because of the coevolved responses of their favored food plants, areas that have been repeatedly grazed become more attractive for grazing, resulting in a positive feedback of increasing patch heterogeneity across the landscape. Some researchers have shown this effect stemming from a subtle interplay among species with different grazing preferences, for instance, an interactive reinforcement of grassland patch and species diversity among prairie dogs, bison, elk and pronghorn in Wind Cave National Park, South Dakota (Detling and Whicker 1987).

In a time when elevated deer populations are devastating structural and species diversity in forests, it is logical to question whether pre-human-settlement grazing might likewise have been too intense to sustain high species and patch diversity in the region's grasslands and meadows. However, then—unlike now—large predators would have kept herbivore population growth in check, hunting year-round and reducing prey species' reproductive rates by nonlethal effects—the so called "ecology of fear" (Ripple and Beschta 2004). For millions of years until 13,000 years ago the Mid-Atlantic Region's fauna included not only gray wolves and mountain lions, but also American cheetah, Studer's cheetah, jaguar, dire wolf, Armbruster's wolf, brown (grizzly) bear, lesser short-faced bear and giant short-faced bear (Cope 1871, 1899; Wheatley 1871; Hay 1923; Guilday 1971; Kurtén and Anderson 1980; Williams at al. 1985; Daeschler et al. 1993). The giant short-faced bear was the largest land predator since the demise of the dinosaurs.

Another way in which animals enhance grassland plant diversity is by changing soil conditions. Contemporary examples include burrowing by prairie dogs (Detling and Whicker 1987) and wallowing by bison. Favored wallowing sites become mosaics of different degrees of soil compaction and selective plant species exclusion. Because of compaction, in the spring some wallows turn into temporary pools that support ephemeral wetland species (Uno 1989). In the summer concentric zones within wallows differ in species composition and often show greater drought and fire resistance than surrounding vegetation (Collins and Barber 1985). Across several scales, the effect of bison wallowing is an increase in environmental heterogeneity and local and regional biodiversity (Hartnett et al. 1997). It reasonable to extrapolate from prairie dog burrows, bison wallows and the massive ecosystem effects of elephants and other surviving megaherbivores (Dublin et al. 1990; Zimov et al. 1995) to surmise that the herbivores of pre-Holocene eastern North America likely had a strong positive effect on patch diversity, and in all probability species richness, in grasslands and meadows.

The evolutionary and ecological history of the region's flora has given rise to grassland/meadow specialist plants of a wide range of growth forms (Table 26), including many short-statured, shade-intolerant species that are highly dependent on a varied disturbance regime and resulting high patch diversity. It is fair to conjecture that the high regional diversity in grassland/meadow plant growth habits reflects a relatively high abundance through evolutionary time of long-persisting grassland and meadow communities, and not simply a shifting mosaic of short-lived open patches created by severe disturbances. Not all indigenous grassland/meadow species are equipped for long-distance seed dispersal or have extraordinary seed longevity. Substantial quantities of suitable habitat had to have consistently lasted for long periods of time in the same locations, or in shifting mosaics that shifted only a little, to allow numerous grassland/meadow species whose seeds rarely travel more than a few meters to persist.

Some lightning-ignited fires may have occurred before humans arrived on the scene, but they were likely rare events. Records of wildfires in today's climate in the northeastern United States seldom attribute ignition to lightning, which is usually accompanied by heavy rainfall and is unlikely to ignite spreading wildfires (Loope and Anderton 1998). Lightning fires in grasslands occur almost exclusively in areas with seasonal precipitation; the wet season sustains high biomass production, the dry season greatly reduces fuel moisture, and the monsoon climate characteristically generates "dry lightning" capable of igniting fires (Keeley and Rundel 2005).

Table 26. **Herbaceous native grassland/meadow species in the Greater Piedmont tallied by longevity class and maximum height.** The tally covers all plants in Appendices D and E excluding woody species.

longevity class	very short or prostrate (< 50 cm)	short (50–90 cm)	intermediate (100–160 cm)	tall (170–250 cm)	very tall (≥ 260 cm)	total
perennial	81	168	143	116	14	522
biennial	3	3	3	7	1	17
annual	41	46	24	19	0	130
total	125	217	170	142	15	669

4.6.2 Indian occupation (ca. 13,000–500 years before the present)

There is some evidence that humans may have lived in the Mid-Atlantic Region 14,500 years ago or earlier (Adovasio et al. 1990), but ecological changes associated with human presence are not obvious in the fossil record before about 13,000 years ago. Around then, during a period of about 1,000 years, there was a ten-fold rise in graminoid charcoal followed closely by the near-disappearance of spores of the fungus *Sporormiella*, which specializes on the dung of large herbivores (Robinson et al. 2005). Although evidence is still lacking on the exact cause, the extinctions of the megaherbivores—native elephants and giant ground sloths—and most of the large and mid-sized herbivores occurred simultaneously with a wave of human immigration or cultural change. The extinctions were formerly attributed to climate change, but they did not coincide with any climatic shift more rapid or severe than many others not associated with mass extinctions that had occurred earlier in the Quaternary before the arrival of humans (Burney and Flannery 2005).

There is stratigraphic evidence for abrupt changes in fire regime and vegetation at various times during the Holocene epoch at scattered locations across eastern North America (Clark and Royall 1996; Delcourt and Delcourt 1997, 1998; Robinson et al. 2005). Independent evidence is lacking linking the timing of these changes to localized climate shifts; a more parsimonious explanation is that humans adopted fire as a landscape management tool at different times and in certain places, corresponding with areas of cultural influence. Agreement among paleoecologists is emerging that the vast area and near-omnipresence of grasslands in the tallgrass prairie region of central North America is largely due to a long history of burning by humans (Axelrod 1985; Anderson 2006). The smaller areas of grassland in the eastern North American forest region at the time of European first contact were doubtless of similar origin. Ironically, when human-set fires began opening up grasslands in central and eastern North America thousands of years ago, they had the unintended effect of restoring some of the habitat diversity that had declined when the megaherbivores died out (Bond and Keeley 2005), a catastrophe that had been caused, directly or indirectly, in all probability by the fire-setters' ancestors (Burney and Flannery 2005).

Eyewitness accounts of burning practices, together with circumstantial evidence provided by descriptions of grasslands, meadows and shrublands at around the time of earliest European settlement (Appendix B, pp. 133-151), suggest that the late-prehistoric use of fire to manage the landscape was common, practiced by various nations and tribes across the Mid-Atlantic Region. There are many eyewitness accounts of deliberate use of fire on the landscape by Indians all across North America (reviewed in Day 1953; Whitney 1994; Stewart 2002), but only a few from the territory of the Lenape, the main inhabitants of southeastern Pennsylvania around the time of European contact (e.g., Denton 1670; Coates 1906; Myers 1912; Lindeström and Johnson 1925). Documentation exists from many sources (Stewart 2002; Brown 2004) suggesting that Indians conducted burns most likely to improve game habitat, encourage the growth of certain fire-enhanced sources of food such as blueberries, huckleberries, blackberries, and raspberries, and extend visibility, which would have made it easier to hunt, travel, and maintain "homeland security." One of the consequences was a relative abundance of grasslands, meadows, and shrublands covering perhaps 1% or 2% of the total land area around the time of European settlement, comparable to the entire area in wetland vegetation (Latham 2005).

The ecological effects of widespread, frequent fire differ in some ways from the patchy browsing and grazing and severe soil disturbance characteristic of mega-, large and mid-sized herbivores. However, fire effects are typically also patchy. Fire very likely shared grazing's characteristic of self-patterning (de Knegt et al. 2008). Repeated burning led to even more burning in the same locations in a positive feedback, with a site's history of repeated burning leading to higher attractiveness as a place to burn again. It is well known that burning severity varies with spatial heterogeneity of fuels, for instance, dead trees that are dry enough to ignite burn longer and hotter than grasses, and some communities such as wetlands resist burning entirely, except during severe droughts. Burning severity is strongly influenced by weather. There is no compelling reason to think that Indians would have avoided burning during droughts as we do today. Historical accounts make clear that those who engaged in large-scale burning understood fire behavior and would have been capable of minimizing casualty risk. Risks to infrastructure were much lower before European settlement of the Mid-Atlantic Region because little infrastructure existed and what there was could be replaced relatively easily. Structures associated with seasonal camps were rebuilt annually and thus expendable. More-permanent settlements were often surrounded by cornfields, which would have protected them against the spread of fire.

Seasonality of burning was probably biased toward spring and fall, based on the few word-of-mouth accounts, but may well have occurred in summer as well. Fires in different seasons have somewhat different effects on plants and animals. Spring fires typically favor warm-season grasses and late-summer-flowering forbs. Summer and fall fires favor cool-season grasses and spring-flowering forbs. Late spring and summer fires can reduce certain insect, bird and other wildlife populations. Fire return interval was probably highly variable. There is little historical basis for estimating a "typical" fire return interval. It may have varied culturally and over time, and almost certainly differed considerably by location, at multiple spatial scales.

It is reasonable to conjecture that grasslands in the Mid-Atlantic Region should have undergone a period of decline if there was a significant timespan between the faunal mass extinction and the beginning of widespread landscape-scale application of fire. However, there is no evidence of such a hiatus in the Midwestern prairies (Gill et al. 2009). In any case, with humans on the scene, accidental escapes from heating, cooking and ceremonial fires were a possibility. Furthermore, during the Hypsithermal interval between 8,000 and 4,500 years ago—the most recent major episode of global warming—eastern North America had greater seasonal variation in precipitation and perhaps more lightning-ignited fires (Deevey and Flint 1957).

4.6.3 European contact, early settlement and Indian depopulation (ca. 1500–1800)

European settlement is associated with the sudden, widespread near-cessation of burning. The demise of the old disturbance regime actually preceded European settlement in many areas with the collapse of indigenous human populations due to waves of introduced diseases such as smallpox from European exploratory expeditions and settlements far away (Denevan 1992; Mann 2005). Forest succession quickly ensued in much of the open grassland or meadow area and most of the rest was replaced with crop monocultures by farmers using steel plows. Europeans also introduced many nonnative species, some of which could proliferate unchecked because the native herbivores avoided them. However, botanical records suggest that few plants' populations reached invasive levels before the nineteenth century.

Native grasslands and meadows lived on in altered form as fallow fields. Colonial-era farms rotated fields through periods of fallow to permit some recovery of soil fertility. Fletcher (1955) summarized the crop rotation and fallowing practices of the late eighteenth century in southeastern Pennsylvania:

> Within a generation after the first farms were established along the Delaware there were signs that the soil fertility account in the land bank was getting low, if not already over-drawn. By 1730 … on most farms within forty miles of Philadelphia the wheat yield had declined from an average of 20 to 30 bushels an acre to ten bushels, and even less. In 1791 Richard Peters of Philadelphia reported to George Washington, "About 8 bushels of Wheat per acre is a full allowance for the better kind of farms in these parts. Some do not yield 6, and 8 out of 10 do not come up to 8 bushels per acre." … There were two sovereign remedies for impoverished fields—to abandon them completely and clear new ground or to "rest" them for several years in fallow, which usually meant letting them grow up in weeds and sprouts. … The situation in the southeastern counties … was set forth by Peter [Pehr] Kalm, in 1749; "Agriculture is in a very bad state hereabouts. … After being cultivated for several years in succession, without being manured, the land finally loses its fertility. Its possessor then leaves it fallow and proceeds to another part of his land, which he treats in the same manner. Thus he goes on till he has changed a great part of his possessions into grain fields. … He then returns to the first field,

> which now has pretty well recovered. This he tills again as long as it will afford him a good crop; but when its fertility is exhausted he leaves it fallow again and proceeds to the rest as before." (Francis Alison, *Early Proceedings of the American Philosophical Society from 1744 to 1838*, pp. 78-79) The fallow period might be from seven to fifteen years. [Fletcher 1955, pp. 124-125]
>
> All-grain rotations continued to dominate the agriculture of southeastern Pennsylvania until about 1790. On the western frontier they persisted longer. In 1794 Cazenove found that the prevailing course of crops in Lebanon County on new ground was a six year rotation: 1 and 2, wheat; 3, oats; 4, fallow; 5, wheat; 6, fallow. On land that had been in cultivation a number of years a five year rotation was followed: 1, wheat; 2, barley; 3, corn or oats; 4, fallow or buckwheat; 5, buckwheat or fallow (Theophile Cazanove, *Cazenove Journal, 1794* [Haverford 1922], pp. 48-49). Even more exhausting was the fourteen year rotation reported in Lehigh County in 1775: 1, 2, wheat; 3, corn; 4, 5, wheat; 6, 7, 8, barley; 9, 10, oats; 11, buckwheat; 12, 13, oats; 14, peas. Then the exhausted land was fallowed in weeds for seven or more years before being brought again under the plow (*American Husbandry*, "By An American" [1775], I, 171-172). [Fletcher 1955, p. 128]

Extensive fallowing was the rule until after 1800, even though sustaining soil fertility by alternating grain crops with legumes such as red clover had been recommended in the first American book on agriculture, by Jared Eliot, in 1748 (Fletcher 1955). Although Pennsylvania Germans had been practicing soil fertility conservation measures from the start in other parts of Pennsylvania, it was not until after 1800 that farmers of English descent, such as those at Valley Forge, widely adopted the system of adding lime and manure to soils and growing corn, wheat and oats or barley in a six-year rotation that included two consecutive years of mixed legumes and grasses, mainly red clover, timothy and orchard grass, which served as pasture for livestock. These practices "remained the dominant course of crops of southeastern Pennsylvania" through the mid-twentieth century (Fletcher 1955).

Estimates of the proportion of farm fields in the mid- to late eighteenth century around Valley Forge that was in fallow at any given time based on the information compiled by Fletcher (1955) are in the range of 17%–33% of the total cropland area. Although it is unlikely that any documentation exists of their species composition (other than observations in the late 1740s of typical old-field tree species by the Swedish botanist Pehr Kalm; see pp. 141-144 in Appendix B), it is a fair assumption that it consisted of various combinations of native grassland and meadow species intermixed with European grass species planted as forage for livestock.

4.6.4 Recent major ecological changes—proliferation of invasive plants, white-tailed deer and nonnative earthworms

By all accounts it was not until the late 1800s at the earliest that a few naturalized nonnative species in the region began reaching an exponential phase of population increase and becoming widespread and invasive (Crooks and Soulé 1996; Randall 1996; Latham and Rhoads 2006). The most abundant plants of this type in the park's grasslands and meadows today are stiltgrass (*Microstegium vimineum*), Japanese honeysuckle (*Lonicera japonica*), common mugwort (*Artemisia vulgaris*), quackgrass (*Elymus repens*), Oriental bittersweet (*Celastrus orbiculatus*), yellow foxtail (*Setaria pumila*), butter-and-eggs (*Linaria vulgaris*) and hairy chess (*Bromus commutatus*).

Remnants of hay and forage grass plantings also persist in abundance, including meadow fescue (*Schedonorus pratensis*), sweet vernalgrass (*Anthoxanthum odoratum*), Kentucky bluegrass (*Poa pratensis*), red fescue (*Festuca rubra*), orchardgrass (*Dactylis glomerata*), redtop (*Agrostis gigantea*), tall oatgrass (*Arrhenatherum elatius* var. *biaristatum*) and timothy (*Phleum pratense*). All are cool-season species native to Europe and commonly planted in Pennsylvania hayfields and pastures. Some, such as sweet vernalgrass and redtop, have not been in regular agricultural use for 50 years or more.

Although certain nonnative plants, such as cool-season grasses planted for fodder, can provide high-quality sustenance for Old World grazers such as cattle and horses, nonnative plants' food value for most native wildlife, especially for the insects on which the entire food web is critically dependent, is low (Tallamy 2004, 2007, 2008; Burghardt 2008). Nonnative plants, which are currently more abundant than natives in VAFO grasslands and meadows, provide little to nothing of use to native animal life.

Insects are vital links in most of the food chains that make up the food web in terrestrial ecosystems. Most insect species are specialist feeders on just one native plant species or a narrow range of species. The close associations between the insect and plant species native to a region developed over tens of thousands to millions of years. Nonnative invasive plants seldom are utilized as a food resource by native insect species, which is one of the reasons why they are invasive. Insects are the richest source of fats and protein for small birds and many other small animals including predaceous insects, spiders, salamanders, frogs, toads, small snakes, shrews, moles, bats and rodents; all of these, in turn, are food for larger animals. Far less of the total plant biomass is converted, via the food chains that make up the food web, into animal biomass where nonnative plants are abundant. The higher the cover and species richness of native plants in a patch of grassland or meadow, the higher the total insect biomass will be, which, in turn, enables native wildlife species to reach and sustain high population density and minimizes the risk of extirpation. Sharply reducing the biomass of nonnative plants in the park's grasslands and meadows has the potential to appreciably increase bird numbers and diversity.

Until the recent implementation of a deer management plan in the park, the white-tailed deer population had not been regulated by predation for many decades and thus had extreme effects on relative plant species abundances and other ecosystem attributes. For more than 99% of the past 2.6 million years, mammoths, mastodons, ground sloths, elk, moose, two now-extinct deer species, giant beaver, horses, tapirs and peccaries coexisted with white-tailed deer. It is axiomatic in ecology that coexisting herbivore species differ in their food-plant preferences and other aspects of feeding behavior. The diverse suite of large herbivores with a wide variety of feeding habits and other community-level interactions had robust effects on ecosystems, but very different effects from those resulting from an outsized, unregulated population of white-tailed deer as the sole survivor.

Deer are a natural part of the region's ecosystems, but an unintended convergence of events caused them to proliferate to unprecedented population densities by the latter half of the twentieth century. For the first two centuries after William Penn's arrival, the human population grew exponentially and unlimited hunting eroded the delicate balance that had prevailed for eons between predators—including the pre-European-settlement human population—and deer. By 1900, deer were nearly extinct in Pennsylvania and other eastern states because of over-harvesting. At the same time, the natural predators of deer had been exterminated. State agencies instituted game laws in an effort to rebuild the deer population. The hunting rules, which have persisted with few major changes to the present, focused on providing a maximum sustained yield of game for recreational hunters. Deer reproduce rapidly and the deer population soared to unprecedented levels in just a few decades.

Deer populations are no longer kept at ecologically sustainable levels as they were for more than 99% of the last 2.6 million years, for nearly all of that time by large predators and for most of the past 13,000 years also by Native Americans, for whom venison was a major source of food. A diverse array of predators regulated deer populations for millions of years before humans arrived in our region, including the timber wolf, dire wolf, grizzly bear, giant short-faced bear, mountain lion, American cheetah, and jaguar (Cope 1871, 1899; Wheatley 1871; Hay 1923; Guilday 1971; Kurtén and Anderson 1980; Williams at al. 1985; Daeschler et al. 1993). Human hunters arrived in what is now southeastern Pennsylvania at least 13,000 years ago, forcing out most of the other major predators, but Indians, timber wolves, and mountain lions continued to regulate deer populations until Europeans arrived and expelled all three. Recreational hunting as it is practiced today under strict game laws and for only a short interval in the fall has relatively little impact on deer population numbers. In any case, hunting is even more tightly restricted or prohibited altogether in most suburban areas, including VAFO and vicinity.

Deer thrive best in forest-edge habitat, which describes essentially the entire park. The unprecedented high numbers that exist today consume the tree seedlings and saplings, shrubs and wildflowers that in more favorable circumstances make native forest and grassland ecosystems healthy, beneficial to wildlife and self-sustaining. Most of the forest in the park has been stripped of understory vegetation. The dense layer of native shrubs, young trees, ferns and wildflowers that are the hallmark of a healthy forest is sparse or, in many areas, missing. The understory now is typically either largely devoid of plant life or choked with nonnative invasive species. Deer and other herbivores generally pass up nonnative invasive plants, which is one of the reasons those plants can proliferate unchecked.

The legacy effects of long-term deer overabundance on grasslands and meadows are more subtle than its obvious severe impact on the park's forest ecosystems (Lovallo and 2003; Largay and Sneddon 2007). Grassland and meadow plants are adapted to disturbance, including grazing and browsing. However, the species that are highly preferred by deer have had little chance against the onslaught at extreme deer population density, which at its peak may have been 20 or more times as high as it was through the ages. White-tailed deer are primarily browsers and in one sense a high deer population benefits grasslands and meadows by slowing forest succession. However, during the summer deer are also voracious grazers, almost exclusively on forbs, and in that role they can have considerable impact on species diversity in grasslands. Studies of impacts of artificially elevated deer populations are relatively plentiful for forest ecosystems in the region (reviewed in Latham et al. 2005) and a few exist for working agricultural landscapes in national parks (e.g., Stewart et al. 2007). The literature on white-tailed deer effects on native grasslands and meadows in eastern North America is nonexistent, but there is one relevant set of studies from a Midwestern tallgrass prairie.

In a study of high-density deer effects on plant diversity in a tallgrass prairie in Illinois (Anderson et al. 2001), deer grazing pressure fell disproportionately on several plants that are also a part of the grassland and meadow flora of the Greater Piedmont, including flowering spurge (*Euphorbia corollata*), stiff goldenrod (*Solidago rigida*), Ohio spiderwort (*Tradescantia ohiensis*), Culver's-root (*Veronicastrum virginicum*) and congeners of local tick-trefoils (*Desmodium*), sunflowers (*Helianthus*), alum-roots (*Heuchera*), mountain-mints (*Pycnanthemum*), hedge-nettles (*Stachys*), asters (*Symphyotrichum*) and vetches (*Vicia*). In the same study, all grasses and sedges but few forbs were avoided by deer, including only three in common with Greater Piedmont grasslands and meadows—American fever-few (*Parthenium integrifolium*), arrowleaf violet (*Viola sagittata*) and the nonnative common yarrow (*Achillea millefolium*). Ten years of study at the same site compared plant community effects before and after a five-fold reduction in deer density and between ambient conditions and fenced deer exclosures. The researchers concluded from their results that diversity of grassland forbs is highest at low levels of deer grazing, significantly higher than where deer are excluded (Anderson et al. 2005).

Among native grassland/meadow species in the Greater Piedmont, plants highly vulnerable to deer browsing and grazing include nearly all of the tree (as seedlings) and shrub species (p. 234 in Appendix D and p. 251 in Appendix E). Forbs known anecdotally to be especially vulnerable include members of the lily family, such as wood lily (*Lilium philadelphicum*) and Canada lily (*Lilium canadense*), and the orchid family, including ladies'-tresses (eight species in the genus *Spiranthes*) and fringed-orchids (five species in the genus *Platanthera*). Great Plains ladies'-tresses (*Spiranthes magnicamporum*), slender ladies'-tresses (*Spiranthes tuberosa*) and crested fringed-orchid (*Platanthera cristata*) historically lived in the counties surrounding VAFO but are now extirpated from Pennsylvania, possibly in part due to deer feeding pressure. Several other forb species of special conservation concern are considered to be at risk for extirpation by elevated deer populations (Latham et al. 2005).

Deer overabundance has a direct connection with the proliferation of invasive plants. Deer facilitate nonnative plant invasion in at least two ways. First, deer are important dispersers of invasive species' seeds (Myers et al. 2004). They excrete large number of live seeds due to the large volume of food they consume and because their ruminant digestive physiology tends to allow seeds to pass through unharmed. Moreover, deer range over larger territories than most other seed dispersers except birds, whose diets include a narrower range of seeds and whose gizzards crush and digest a high proportion of the seeds they eat. Secondly, research in forest understories has shown that deer preferentially feed on native species and tend to avoid most nonnative invasive species. Where deer are superabundant for several decades, the result is an essentially irreversible dominance of forest understories by one or a few unpalatable species (Augustine et al. 1998) such as Japanese stiltgrass (*Microstegium vimineum*) or garlic mustard (*Alliaria petiolata*) (Knight et al. 2009). Until shown otherwise, it should be assumed that similar phenomena contribute to shaping plant species composition in grasslands and meadows where the deer population has been extraordinarily high for many years, as it has at VAFO.

The effects of nonnative invasive earthworms in eastern North American grasslands and meadows are still poorly understood, but they have been found to be profoundly disruptive in forest ecosystems (e.g., Burtelowa et al. 1998; Hendrix and Bohlen 2002; Nuzzo et al. 2009). The main beneficiaries of nonnative earthworm invasion in forests are nonnative invasive plants, including stiltgrass (Nuzzo et al. 2009), which is at present the most abundant of all species, native or nonnative, in VAFO grasslands and meadows (Table 16, p. 41). No effective treatment to stem exotic earthworm proliferation is yet known.

Ecosystem-shaping disturbances prior to European settlement had generally positive effects on grassland/meadow ecosystems but those that have had the strongest impacts in the last century have been mostly detrimental to ecological integrity. In addition to the population explosions of invasive plants, white-tailed deer and invasive earthworms, fire exclusion since European settlement has also exerted strong adverse effects on the region's grasslands and meadows and their component native plant and animal species.

For several thousand years prior to European settlement, grasslands and meadows in the region were stabilized by frequent fire and also by a feedback effect between fire tolerance and what some ecologists have termed "pyrogenicity," or "fire facilitation" (Bond and Midgley 1995; Zedler 1995). The feedback aspect stems from the co-occurrence in many of the dominant plants, mainly the perennial warm-season grasses, of two sets of traits. One set confers the means to survive even high-intensity fires, including abundant carbohydrate reserves in underground storage organs, rhizomes with abundant dormant buds that produce new shoots when existing shoots are damaged or destroyed, and the predominance of vegetative reproduction (Philpot 1977; Collins and Gibson 1990). The other set of traits confers exceptionally high combustibility to aboveground biomass and litter. It includes a high surface-to-volume ratio, high dead-to-live tissue ratio, fine dry biomass close to the ground, high litter resistance to decomposition, and low water-absorbing and water-holding capacity of surface litter (Philpot 1977; Rundel 1981; Gagnon et al. 2010). Most ecosystems in the region are either fire-resistant (non-flammable except during extreme drought) or subject to infrequent, low-intensity ground fires. By contrast, in grasslands dominated by native warm-season grasses, ignitions are much more likely to spread quickly across large areas and burn at intermediate to high intensity.

The principal detrimental effects of fire exclusion in eastern North American grasslands and meadows are invasion by fire-sensitive woody plants, continued dominance by fire-sensitive nonnative herbaceous species, and buildup of a dense grass thatch layer that inhibits establishment of native forbs. Herbaceous native grassland/meadow plants in the Greater Piedmont are mostly fire-tolerant, some exceptionally so (Tyndall and Hull 1999; Arabas 2000; Laughlin 2004). Annual mowing can fend off tree and shrub invasion but not invasion by woody vines. Mowing is ineffective in reducing populations of most herbaceous nonnative plants and, unless mowed biomass is collected and removed, only intensifies thatch buildup. The three most common plant species (69%–78% frequency) and five of the ten most abundant plant species (60% total average cover) in VAFO grasslands and meadows are nonnative cool-season grasses (Tables 15 and 16, pp. 40, 41). Burning in late spring is the only practical and effective control for these plants (Uchytil 1993; Stone 2010). Management with herbicides is impractical because of the species' pervasiveness and high abundance and the potential risks to native grassland/meadow plants of broadcast application, as well as to amphibians, other organisms, water quality and human health. Fire exclusion effects can be remedied by establishing a fire management program, using periodic prescribed burning as a routine management tool (see *Simulating effects of historical disturbance regimes*, pp. 263-266).

5 Desired Conditions, Metrics and Target Values

This section describes specific, measurable desired conditions for grasslands and meadows in Valley Forge National Historical Park. Desired conditions are attributes considered vital to restoring and maintaining ecosystems to a high standard of ecological integrity. They are based on pre-European-settlement conditions, but of necessity they also take into account irremediable constraints on recreating historical conditions such as landscape isolation, invasive species populations, missing (extirpated or extinct) species that are infeasible to restore, and other historical changes at landscape and regional scales beyond park boundaries.

An essential element is a set of metrics or indicators used to evaluate and communicate ecosystem conditions, with a range of target values for each. Metrics are quantitative attributes of specific ecosystem elements that can be measured or calculated from measurements taken at regular intervals to monitor conditions as they change over time.

The first four subsections give a qualitative description of VAFO grasslands and meadows a few decades from now under the scenario of a native grassland and meadow reclamation program guided by this desired condition analysis. The main goals are to meet a high standard of ecological integrity and to conserve native biodiversity with a particular focus on sensitive habitats of imperiled, rare or declining species, while preserving historical resources and providing visitors with a sense of the eighteenth-century landscape.

A bullet-point summary of the desired conditions comes first, followed by a summary of major ecosystem stressors and their sources and effects (Table 27, pp. 86-87) and a narrative presenting additional details on desired conditions. The narrative is organized in three broad subject areas: (1) desired species diversity and composition, (2) desired structural, patch and habitat diversity, and (3) desired ecosystem processes.

The last part of this section is quantitative and highly specific—a translation of findings presented in *Results* into a set of metrics to serve as the basis for monitoring. Ranges of values for each measured indicator are ranked as excellent, good, fair or poor (see *Methods*, p. 28). Where known, the present status in VAFO grasslands and meadows is given for each metric.

5.1 Qualitative Summary of Desired Conditions

5.1.1 Desired conditions of grassland/ meadow plant communities and landscape

- Dominance by native herbaceous grassland/ meadow plant species in all patches
- High within-patch native grassland/meadow plant species diversity
- High between-patch diversity in native grassland/meadow plant species composition, including dominant species
- Co-dominance by a mixture of native perennial grasses (warm-season and cool-season) in patches comprising at least half of the total grassland/meadow area
- Co-dominance by a mixture of native grassland/meadow forbs in a substantial minority of patches

5.1.2 Desired conditions of grassland-interior bird habitat

- High grassland/meadow contiguity (low fragmentation)
- A diverse mixture of patches dominated by relatively sparse, short grasses and forbs and more densely occupied patches dominated by intermediate to tall grasses and forbs

- Substantial areas of bare ground in patches dominated by short grasses and forbs
- Sparsely scattered shrubs

5.1.3 Desired conditions of butterfly habitat

- Continuity of overall nectar abundance throughout the growing season
- High abundance of key host plant species:
  - violets (10 *Viola* taxa listed in Appendix D)—larval host plants for regal fritillary (G3/S1) and other fritillaries
  - native thistles (5 *Cirsium* species listed in Appendices D, E)—key nectar plants for regal fritillary (G3/S1) and many other species
  - milkweeds (10 *Asclepias* species listed in Appendices D, E)—key nectar plants for regal fritillary (G3/S1) and many other species
  - ragworts (4 *Packera* species listed in Appendices D, E)—larval host plants for northern metalmark (G3/S1S2)
  - blue lupine (PR; recorded historically in park)—larval host plant for frosted elfin (G3/S1S2)
  - wild indigo (recorded historically in park)—larval host plant for frosted elfin (G3/S1S2)
  - New Jersey tea (SP)—larval host plant for mottled duskywing (G3G4/SH)

5.1.4 Desired conditions of grassland/meadow plant and animal species of special conservation concern

- Secure population status of grassland/meadow plants of special conservation concern present in the park:
  - bushy bluestem (PR)
  - Elliott's beardgrass (PR)
  - slender three-awn (TU)
  - soft fox sedge (SP)
  - Leavenworth's sedge (SP)
  - blue mistflower (SP)
  - slender crabgrass (SP)
  - St. Andrew's-cross (PT)
  - narrowleaf bush-clover (PE)
  - water smartweed (SP)
  - sand blackberry (PE)
  - branching bur-reed (PE)
  - gammagrass (PE)
  - Appalachian ironweed (PE)
  - grassland/meadow plants of special conservation concern that were present historically in the park, in the event of future rediscovery or reintroduction
  - grassland/meadow plants of special conservation concern that are native to the region, in the event of future introduction in the park to enhance range-wide security or adapt to climate change
- Secure breeding status of grassland birds nesting in the park:
  - bobolink
  - eastern meadowlark
  - other grassland birds, in the event they establish nesting populations
- Secure status of grassland birds with significant overwintering presence in the park:
  - barn owl (CR)
  - other grassland birds, in the event they establish significant winter residency
- Secure population status of butterflies of special conservation concern present in the park:
  - mottled duskywing (G3G4/SH)
  - Leonard's skipper (G4/S3S4)
  - cobweb skipper (G4G5/S2S3)
  - swarthy skipper (G5/S2S3)
  - mulberry wing (G4/S3)
  - long dash (G4/S3)
  - southern cloudywing (G5/S3S4)
  - brown elfin (G5/S3S4)
  - juniper hairstreak (G5/S2S4)
  - Henry's elfin (G5/S1S3)
  - frosted elfin (G3/S1S2)
  - eastern pine elfin (G5/S3)

- white M hairstreak (G5/S3S4)
- coral hairstreak (G5/S3S4)
- tawny emperor (G5/S3S4)
- silvery checkerspot (G5/S3S4)
- northern pearly eye (G5/S3S4)
- other butterflies of special conservation concern, in the event they establish residency in the park

5.1.5 Desired conditions of ecosystem resilience

- Long-term stability across entire range of indicators
- Stability of indicators following severe drought
- Stability of indicators in the event of unforeseen major perturbation

5.2 Species Diversity and Composition

5.2.1 Plants

The most dramatic change from current to desired conditions in VAFO's grasslands and meadows will be a shift in the dominant species from herbaceous and woody nonnatives to herbaceous natives. Another major change will be from mostly tall, dense grassland/meadow vegetation to a diverse mosaic of tall to short herbaceous species in densely to sparsely covered patches.

A dense growth of tall plants is typical of grasslands and meadows in a year-round moist climate and especially in agriculturally altered soils with excess nutrient availability compared to native soils (see *Community structure* and *Soil fertility*, below). The usual trend over time, with a disturbance regime in place sufficient to sustain grasslands and meadows (i.e., to kill most tree seedlings and saplings), is for perennial C_4 (warm-season) grasses to gain dominance. The tallest species characteristic of reliably moist (but not wet) soils are Indian-grass (*Sorghastrum nutans*) and big bluestem (*Andropogon gerardii*) and, less commonly, eastern gamma grass (*Tripsacum dactyloides*) and switchgrass (*Panicum virgatum*). Desired genotypes of these species in particular are hard to find. All four species have been widely propagated, interbred and selected from stock that originated in the Midwest and other parts of the species' ranges. Plantings of these species without regard to place of origin have undoubtedly contaminated the gene pools of locally indigenous populations with their wind-borne pollen (more on this later under *Restoration and Management Approaches Consistent with Desired Conditions*).

Warm-season perennial grasses of intermediate height tend to become dominant in areas of low to moderate soil nutrient availability or areas that regularly experience low moisture conditions. The most common desired species are little bluestem (*Schizachyrium scoparium* var. *scoparium*) and broomsedge (*Andropogon virginicus*). Others that occur as scattered plants or in localized patches include wirestem muhly (*Muhlenbergia frondosa*), beaked panic-grass (*Panicum anceps*), perennial foxtail (*Setaria parviflora*) and purpletop (*Tridens flavus*). Where soils are least fertile or moist, these same species grow more sparsely and intermixed with desired short-statured warm-season grasses, including Elliott's beardgrass (*Andropogon gyrans*), fall witchgrass (*Digitaria cognata*), purple lovegrass (*Eragrostis spectabilis*), red-top panic grass (*Panicum rigidulum*), field beadgrass (*Paspalum laeve*) and slender beadgrass (*Paspalum setaceum* var. *muhlenbergii*).

Extremely low-nutrient, droughty or highly eroded soils are habitat for these same short-statured species as well as desired warm-season *annual* grasses, including slender three-awn (*Aristida longespica* var. *longespica*), prairie three-awn (*A. oligantha*), slender crabgrass (*Digitaria filiformis*), rough barnyard grass (*Echinochloa muricata*), lacegrass (*Eragrostis capillaris*), witchgrass

Table 27. **Summary of major stressors affecting the ecological integrity of grasslands and meadows in Valley Forge National Historical Park**.

stressor	source(s)	effect(s)
High abundance of nonnative invasive plants	Long history of nonnative occupation of the site resulting in massive, tenacious root systems Constant, prolific and diverse influx of nonnative species' seeds Long-lived soil seed bank of nonnative species Selective avoidance of nonnatives as food by native herbivores (mainly insects, mammals) and as hosts by native parasites, which do not share coevolutionary histories with nonnative invasive species	Displacement of native grassland/meadow plants, resulting in reduced population numbers, extirpation and cascade of effects throughout the food web (see next stressor) Homogenization of wildlife habitat and vegetation at the landscape scale, degrading diversity among patches Hazards associated with particular species, e.g., explosive combustion and lofting live embers from clumps of Chinese silvergrass (*Miscanthus sinensis*) during prescribed burns
Low abundance of native grassland/ meadow plants	Displacement by nonnative invasive species that are more effective competitors in soils altered by a long history of agriculture Selective consumption by native insect and mammalian herbivores and damage by native parasites, which share coevolutionary histories with native grassland/meadow plant species and are adapted to overcome or bypass their defenses	Heightened risk of extirpation Lowered probability of reestablishment Weakened ecological function, including: • low productivity of native herbivores, including many butterflies and other insects that specifically depend on native grassland/meadow plant species, resulting in … • low productivity of insectivores, including grassland birds, resulting in … • low productivity of predators of herbivores, insectivores, resulting in … • heightened risk of extirpation and lowered probability of colonization of native herbivorous, insectivorous or predatory wildlife species
Altered soil fertility and structure	Residuum from centuries of plowing, fertilizer application, cultivation of nonnative monocultures Swift turnover of nutrients from decomposition due to highly labile chemical makeup of nonnative plants' biomass and altered soil animal, fungal and bacterial composition Mown biomass left in place as thatch	Strong dominance by fastest- and tallest-growing species (including nonnatives) Homogenization of wildlife habitat and vegetation at the landscape scale Scarcity of areas dominated by short-statured plants and areas of sparse vegetation—key habitats for many grassland/meadow plants and animals of special conservation concern
Forest succession	Interruption of tree-killing disturbance regimes such as large-herbivore grazing and browsing, fire, mowing	Suppression of grassland/meadow vegetation by shading and altered soil and root dynamics
Grassland/ meadow fragmentation	Fencerows and clumps of tall trees Roads and roadside trees Narrow forest "peninsulas" extending from large forest blocks	Exclusion of wide swaths of grassland/ meadow vegetation adjacent to tall trees as potential breeding territories by grassland-interior birds

stressor	source(s)	effect(s)
Selective herbivory by overabundant deer	Legacy of prolonged, unprecedented high density of white-tailed deer due to lack of population regulation by predators Loss of historical species diversity of large herbivores with different feeding preferences to counterbalance selective effects of deer as sole remaining large herbivore species	Population suppression or extirpation of plant species highly preferred by white-tailed deer Increase in relative abundance of nonnative plants, grasses and other non-preferred species

(*Panicum capillare*), smooth panic-grass (*P. dichotomiflorum*), Philadelphia panic-grass (*P. philadelphicum*) and poverty dropseed (*Sporobolus vaginiflorus*).

C_3 (cool-season) grasses—all perennial—are important components of native grasslands and meadows, although unlike warm-season species they are rarely dominant except occasionally in small patches. Desired tall species growing in moist soils include deer-tongue (*Dichanthelium clandestinum*), riverbank wild-rye (*Elymus riparius*), Virginia wild-rye (*E. virginicus*) and rice cutgrass (*Leersia oryzoides*). Desired species of intermediate height that inhabit a wide range of soils include autumn bentgrass (*Agrostis perennans*), wavy hairgrass (*Deschampsia flexuosa*), tapered rosette grass (*Dichanthelium acuminatum*), Canada wild-rye (*Elymus canadensis* var. *canadensis*) and nodding fescue (*Festuca obtusa*). Desired short-statured species that are highly tolerant of low-nutrient or dry soils include northern oatgrass (*Danthonia compressa*), poverty oatgrass (*D. spicata*), Bosc's panic-grass (*Dichanthelium boscii*), oval-leaf panic grass (*D. commutatum* ssp. *commutatum*), poverty panic-grass (*D. depauperatum*), slimleaf witchgrass (*D. linearifolium*) and shining wedgegrass (*Sphenopholis nitida*).

On soils derived from calcareous bedrock or unconsolidated sand and gravel, especially where the soils are thin, conditions often favor somewhat different sets of desired species from bedrock of non-calcareous composition (specialized tolerances are listed by species in Appendices D and E, pp. 207-252), although the differences are usually slight. Calciphiles typically are subordinate species in grasslands and meadows underlain by calcareous soils. Such communities are most often dominated by many of the same species that are dominant in non-calcareous grasslands and meadows, although they may differ in relative percent cover. Desired species characteristic of calcareous soils and found historically at Valley Forge include man-of-the-earth (*Ipomoea pandurata*), anglepod (*Matelea obliqua*), roundleaf ragwort (*Packera obovata*) and horse-gentian (*Triosteum perfoliatum*). Other calciphiles that may once have occupied soils derived from the Elbrook and Ledger Formations—calcareous rocks underlying the southern and southeastern parts of the park—include whorled milkweed (*Asclepias verticillata*), side-oats grama (*Bouteloua curtipendula*), prairie sedge (*Carex prairea*), Wood's sedge (*C. tetanica*), downy hawthorn (*Crataegus mollis*), downy willow-herb (*Epilobium strictum*), shining ladies'-tresses (*Spiranthes lucida*) and prickly-ash (*Zanthoxylum americanum*). All were or are still found growing in similar soils nearby and are desired species for introduction in the park.

In reliably moist soils, tall forbs and non-grass graminoids are typically scattered in intermixture with the grasses and dominant in patches. In the present VAFO flora desired species commonly include common milkweed (*Asclepias syriaca*), grassleaf goldenrod (*Euthamia graminifolia*), late goldenrod (*Solidago altissima*) and Canada goldenrod (*S. canadensis*). Some of the more common plants among many other desired Greater Piedmont species are Indian-hemp (*Apocynum *cannabinum*), greater straw sedge (*Carex normalis*), hollow-stemmed joe-pye-weed (*Eutrochium fistulosum*), sweet-scented joe-pye-weed (*E. purpureum*), thinleaf sunflower (*Helianthus decapetalus*), rough sunflower (*H. divaricatus*), round-headed bush-clover (*Lespedeza capitata*), tall white beard-tongue (*Penstemon digitalis*), northern bracken fern (*Pteridium aquilinum*), wrinkle-leaf goldenrod (*Solidago rugosa*), New England aster (*Symphyotrichum novae-angliae*), heath aster (*S. pilosum* var. *pilosum*) and wingstem (*Verbesina alternifolia*). Other desired grassland/meadow forbs and non-grass graminoids are listed in Table 24 (p. 66) and Appendices D and E (pp. 207-252).

Wet soils—those experiencing recurring soil saturation—occur in scattered small patches near spring seeps and at the bottoms of swales. They support a substantially different set of native species from moist or droughty soils. Warm-season grasses are generally scarce to absent; cool-season grasses may be present, but are usually subordinate or patchy. The dominant species are usually non-grass graminoids (mainly sedges) and forbs. Plants span the entire gamut of height, from prostrate to 3 m (10 ft.) or more. The range of desired species is vast (Appendices D and E). Examples of common species present in VAFO wet meadows are lurid sedge (*Carex lurida*), fox sedge (*C. vulpinoidea*), false nutsedge (*Cyperus strigosus*), common boneset (*Eupatorium perfoliatum*), water-horehound (*Lycopus americanus*), Pennsylvania smartweed (*Persicaria pensylvanica*) and New York ironweed (*Vernonia noveboracensis*). Other common species in similar situations nearby include bur-marigold (*Bidens cernua*), marsh-purslane (*Ludwigia palustris*), fringed loosestrife (*Lysimachia ciliata*), Allegheny monkey-flower (*Mimulus ringens*), wild forget-me-not (*Myosotis laxa*), wool-grass (*Scirpus cyperinus*) and tall meadow-rue (*Thalictrum pubescens*)

Soils that undergo frequent drought because they are shallow over bedrock or sandy, those that regularly experience saturation (wet meadows), and those where excess nutrients of agricultural origin have already been depleted will support the desired high native species cover and evenness with minimal management. Resource limitations and other stresses characteristic of such soils slow plant growth and inhibit growth of nonnative invasive species. Disturbance sufficient to sustain native grassland or meadow cover (see *Ecosystem Processes*, below) can be less frequent or less severe, or both, on droughty or low-nutrient soils than is necessary on richer, more consistently moist (but not saturated) soils. With droughtiness and low nutrient availability, plants are smaller and grow farther apart and the species composition is biased toward those with high tolerance for dry soils. With recurring soil saturation, the species are mainly those that tolerate low soil oxygen availability.

Compared with present conditions, desired evenness is substantially higher. The shift can be achieved by measures taken to drastically reduce the abundance of nonnative invasive species and by management targeting some of the most abundant native species for periodic reduction (discussed further in the next section). Relative frequencies among native species suggest that evenness would still be low (dominance high) if no other management were to take place besides simply reducing invasive plant abundance. Just six native species are appreciably more common in VAFO grasslands and meadows than in the 99 historical reference sites, scoring at least 10 (up to 47.4) percentage points higher in frequency among samples: broomsedge (*Andropogon virginicus*), common milkweed (*Asclepias syriaca*), common yellow wood-sorrel (*Oxalis stricta*), perennial foxtail (*Setaria parviflora*), horse-nettle (*Solanum carolinense*) and purpletop (*Tridens flavus*). In contrast, among the 330 native grassland/meadow species in the present and historical flora of Valley Forge (Appendix C, pp. 153-206), 189 score at least 20 (up to 46.5) percentage points *lower* in frequency on park survey plots relative to historical reference sites (examples in Table 24, p. 66). The desired increase in abundance of any or all of these species would increase the evenness component of diversity.

Opening up space by severely reducing the cover of invasive nonnative species will foster the desired condition of larger overall native grassland/meadow plant populations than at present, making their long-term viability more secure. The effects of replacing nonnatives with natives will cascade throughout the food web, resulting in larger populations of animals as well, in part by supporting a higher biomass of native insects, which co-evolved with native plants and have adaptations enabling them to overcome or sidestep their defenses.

Plant indicators providing measures of success in restoring and maintaining ecological integrity include:

- population sizes of plants of special conservation concern
- population sizes of plant hosts of butterflies of special conservation concern
- percent cover of native grassland/meadow plants
- native plant species richness, evenness and turnover among patches

Changes in species composition and other ecosystem attributes due to climate change hinge on the characteristics of many individual species and thus are difficult to predict accurately and in detail (Graham and Grimm 1990). The best anyone can do is a set of educated guesses based on the fossil record during past climate changes and knowledge of a large number of living species' tolerances and habitat preferences. There is every reason to expect that, as reclaimed native grasslands and meadows mature, their resilience to climate change will increase. Experimental simulations show that resilience depends on the particular set of species present; however, there is evidence that mature grasslands are highly resilient, and successional or newly reclaimed grasslands considerable less so, to the likely effects of climate change, including elevated CO_2 levels, higher temperatures, more-variable precipitation, and longer droughts (Grime et al. 2000; Adler et al. 2006; Engel et al. 2009). The sooner native grasslands and meadows can be established, the more time they will have to gain qualities that confer stability and resilience as climate change effects grow more severe.

Native grasslands and meadows in all likelihood are more resilient than forests to disruption by global climate change. As climate warms and dries, grassland is likely to need less intensive management to resist forest succession. Frequent drought will kill more tree seedlings and saplings than grassland plants. Lower overall precipitation rates will slow succession. Warming and drying almost certainly will lead to changes in species composition, depending also on localized (patch scale) conditions. Drought-tolerant species are expected to increase in cover and dominance while moisture-demanding species contract. In the long term, the expectation is of range expansions northward of southern species (additions to the local flora), some with a human assist, and range contractions northward of northern species (local extirpations). Grassland and meadow community structural changes are likely to be less dramatic than in Pennsylvania Greater Piedmont forests, where some deciduous-tree-dominated forest types may decline, especially in well-drained soils and on south-facing slopes, possibly with gradual replacement by mixed pine-deciduous forests similar to those currently widespread in the Atlantic Coastal Plain and in the southern Piedmont.

5.2.2 Birds

VAFO's potential breeding bird fauna includes at least 15 species that are referred to as grassland-interior species (marked in Table 19, p. 52-55), that is, in order to nest and successfully rear young they need access to unfragmented grasslands and meadows of tens to hundreds of hectares (1 ha = 2.2 acres). Reclaimed native grasslands and meadows at VAFO will provide one of the largest and highest-quality clusters of habitats in the region for grassland breeding birds.

Until the early eighteenth century, birds in the Greater Piedmont dependent on grasslands included the heath hen (*Tympanuchus cupido cupido*), now extinct (McWilliams and Brauning 2000). The 15 surviving species all are either in decline, imperiled or already extirpated. Two have been confirmed recently as breeding in the park: bobolink and eastern meadowlark (both of maintenance concern in Pennsylvania). Several others are occasional visitors or migrants, including northern harrier, northern bobwhite (Pennsylvania candidates at risk), short-eared owl (endangered), barn owl (candidate rare), horned lark, grasshopper sparrow (maintenance concern), dickcissel (endangered), savannah sparrow and vesper sparrow. They have benefited in recent years by fine-tuning of the seasonal timing of management activities, especially mowing, to minimize impact on bird nesting and fledging.

As desired conditions are attained, habitat will improve for other bird species dependent on native grasslands and meadows in addition to the grassland-interior nesters, including some that are declining and of special conservation concern in the state. The long-eared owl, endangered in Pennsylvania, nests in conifers but forages in grasslands and marshes. The grassland and meadow users American woodcock, prairie warbler, whip-poor-will, Wilson's snipe and yellow-breasted chat are species of maintenance concern. Numerous other birds use grasslands occasionally, including several of special conservation concern (Table 19, pp. 52-55).

Measures of success in establishing VAFO grasslands and meadows as prime habitat for birds include:

- indicators of patch and structural diversity to accommodate the varied needs of the established and potential species (discussed later in this section under *Bird habitat*);
- the share of ecosystem biomass accounted for by native grassland/meadow plants
- long-term stability in the numbers of nesting pairs of grassland-interior birds, once they approach full occupancy of potential habitat

5.2.3 Butterflies

Butterfly species of special conservation concern seen in recent years in the park include two that are globally rare—frosted elfin (G3) and mottled duskywing (G3G4)—and 15 others that are imperiled, rare or declining in the state: brown elfin, juniper hairstreak, Henry's elfin, eastern pine elfin, white M hairstreak, coral hairstreak, tawny emperor, silvery checkerspot, northern pearly eye, Leonard's skipper, cobweb skipper, swarthy skipper, mulberry wing, long dash and southern cloudywing. At least 23 other rare or imperiled butterfly species are also desired potential VAFO grassland and meadow residents (Table 21, pp. 58-60), including the globally rare regal fritillary (G3). The regal fritillary is an endangered species whose habitat requirements are a close match to VAFO grassland and meadow desired conditions. It is a grassland butterfly with only one remaining viable eastern North American population (Latham et al. 2007b), placing it in great jeopardy of extirpation. It lives only where there is a combination of abundant violets (*Viola* spp.), its larval host plant; bunchgrasses (e.g., bluestem, broomsedge and deer-tongue), where adults rest and hide; milkweeds (*Asclepias* spp.), its principal nectar source in the early-summer breeding season; and native thistles (mainly *Cirsium discolor*, *C. muticum* and *C. pumilum*), which females rely on for nectar in late summer when laying eggs (Latham et al. 2007b).

Because of the large number of species in the park's grasslands and meadows and the complexity of their species-specific needs, it is efficient to take a coarse-filter approach, relying on desired conditions for plant communities and treating the rarest butterflies as "umbrella" species, that is, assuming that if their needs are met, chances are high that the needs of many other species will be met. Many of the rare species' larval host plants, cover and resting sites and adult nectar sources are species that are well accounted for by metrics of ecological integrity of plant communities, for instance, abundance of native perennial warm-season grasses such as little bluestem, big bluestem and broomsedge, which are larval host plants for several rare species as well as providing resting sites and cover for adult butterflies of many species.

Metrics to track success in providing for the habitat needs of butterflies include:

- abundance of specific plant species that are hosts for larvae of rare species present in the park and major nectar sources for adults of those and many other species
- continuity of overall nectar abundance throughout the growing season

5.2.4 Other animals

Amphibian and reptile species of special conservation concern observed recently in the park are eastern spadefoot, Fowler's toad, northern leopard frog and eastern box turtle, with six more species regarded as potential park inhabitants (Table 20, pp. 56-57). Restoration efforts have been recommended for northern fence lizard, which has not been recorded in VAFO and whose regional populations are highly fragmented and declining, and black rat snake, a resident but declining species (Tiebout 2003). Two rare mammal species are also considered as potential grassland and meadow residents at VAFO: least shrew, endangered in the state and recorded historically nearby, and southern bog lemming, whose predicted range includes the park (Table 20).

No metrics specifically targeting these species or attributes of their habitats are recommended at this time, but they should be added in the event that special restoration or management programs are undertaken to safeguard or augment populations in the park.

5.3 Structural, Patch and Habitat Diversity

5.3.1 Community and landscape structure

High diversity in grassland and meadow structure and patch type is needed to accommodate a variety of plant and animal species. Community structure is the vertical layering and horizontal arrangement of plants of different sizes and growth forms, including the extent of vegetation cover, canopy closure and bare ground, the type and abundance of dead plants or plant parts, and the amounts and types of decomposing plant material. A patch is a relatively discrete area within a community or ecosystem that is different in some significant way from its surroundings, usually reflected in differences in plant species composition. Structural and patch diversity corresponds to some degree with site features, for instance, patches of wet meadow or marsh, shallow soil, and bedrock exposure. Patch diversity is associated with differences in species dominance and composition arising from variation in land-use, disturbance and management histories, or priority effects—which species arrived and established first after a disturbance.

The desired condition is a diverse mosaic of patch types within each field, differing in successional stage, species composition, vegetation density and vegetation height. In addition to meeting the needs of different plant, bird, butterfly and other native species, such a patchwork is an opportunity for managers to maximize efficiency by using existing soil and other site constraints to advantage rather than trying to change them.

Measures of success in achieving high patch diversity include:

- plant species turnover (different composition) among patches
- frequency of patches with high plant species richness
- relative proportion of grasslands (at least 50% cover of native grasses) and meadows (at least 50% cover of forbs) among patches

- relative proportion of patches dominated by short plants and patches dominated by intermediate to tall plants
- plant density variation among patches

5.3.2 Grassland bird habitat: patch diversity and grassland/meadow contiguity

Grassland birds evolved in communities with high species richness of native grasses and perennial forbs and patchiness in such environmental attributes as litter depth and amount of bare ground, resulting from fires, grazing and browsing, soil scarification by large animals, and runoff- and flood-related soil erosion. They show strong preference for those habitats and they achieve the highest rates of survival and reproduction in them (Peterjohn 2006). Species vary in their habitat requirements, so only a mosaic of patches in different stages of recovery from various intensities of disturbance will support a variety of species. For example, horned larks prefer open areas with sparse vegetation, grasshopper sparrows are most abundant where bunchgrasses are interspersed with patches of bare ground, Henslow's sparrows prefer tall, dense grass cover where there has not been a disturbance for several years, and eastern meadowlarks need dense vegetation with thick litter and scattered trees or other tall singing perches (see Table 28).

> These species originally evolved in native grasslands characterized by high species richness of grasses and perennial forbs, varying litter depths, and varying extent of bare ground resulting from grazing, fires, and other disturbance. Grassland birds prefer comparable structural and species composition within existing grasslands. Monocultures are much less desirable than mixed communities, and monocultures planted at maximum densities create habitats that are too tall and dense to support any grassland birds. [Peterjohn 2006, p. 10]

A large, contiguous habitat area is critical for all grassland bird species, and bird density, diversity and offspring survival increase with the size of a habitat "island." This is partly

Table 28. **Habitat preferences of grassland-interior bird species that nest now or have nested historically in the Greater Piedmont.** Based on information in Peterjohn (2006) and McWilliams and Brauning (2000); adapted from Latham and Thorne (2007). See also Table 19 (pp. 52-55).

species	include patches of bare ground	dense ground litter	patchy, short grasses, forbs	dense, tall grasses, forbs	shrubs (cover or short singing perches)	sparse trees (tall singing perches)	include patches of wet vege-tation
northern harrier				yes			yes
northern bobwhite				yes	yes		
upland sandpiper		avoid		yes			
barn owl						O.K.	
short-eared owl					yes		yes
loggerhead shrike				yes	yes	O.K.	
horned lark	yes		yes				
sedge wren							yes
vesper sparrow	yes		yes		yes		avoid
savannah sparrow			yes		O.K.		avoid
grasshopper sparrow	yes	yes	yes	avoid	yes		
Henslow's sparrow	avoid	yes		yes	avoid		O.K.
dickcissel					O.K.		
bobolink		yes		yes	O.K.		O.K.
eastern meadowlark		yes		yes	O.K.	yes	

because grassland-interior birds, true to that term, avoid nesting in a wide zone of grassland or meadow adjacent to the forest edge, along a fencerow, or even within a circle around a lone tall tree. In Illinois, most grasshopper sparrows, savannah sparrows, bobolinks and Henslow's sparrows were absent from contiguous grassland/meadow patches of less than 30 ha (75 acres) (Herkert 1994a), and this lower limit has been confirmed in eastern states as well (e.g., Vickery 1994). Upland sandpiper needs fields of at least 60 ha (150 acres) (McWilliams and Brauning 2000).

It takes a large contiguous area of grassland to accommodate a habitat mosaic serving the needs of a variety of grassland bird species (Herkert 1994b; see Table 28). As a rule of thumb in the Mid-Atlantic Region, Peterjohn (2006) has suggested that 5–6-ha (12–25-acre) unbroken patches of grassland or meadow sometimes support small sink populations of grassland birds, 10–20-ha (25–50-acre) patches do so more consistently, and a contiguous area of 40–100 ha (100–250 acres) or more may support source populations and multiple grassland bird species.

Some species require song perches within a particular height range where males can advertise their territorial boundaries (Peterjohn 2006). Sedge wrens and Henslow's sparrows sing from on or near the ground and horned larks while airborne. The rest need perches that are strong enough to stay upright while bearing a bird's weight (see Table 28). No grasses and few native forbs can serve the purpose (a non-native forb, common mullein, *Verbascum thapsus*, is regularly used). Sparsely scattered shrubs, small trees and dead snags are among the structural elements critical to most grassland-interior birds.

Measurable indicators of success in creating and maintaining optimal bird habitat include those discussed above under *Birds* (pp. 89-90) and *Community and landscape structure* (p. 91). Additional metrics include:

- grassland/meadow contiguity
- sparse presence of shrubs or small trees

5.4 Ecosystem Processes

5.4.1 Disturbance regime

Regular disturbance is essential to maintain grasslands and meadows against forest succession in most of eastern North America, with its year-round moist climate. However, different disturbances can have very different effects on grassland and meadow ecosystems. Moreover, nuances of disturbance type, seasonal timing, severity and frequency help to determine whether a grassland or meadow becomes a high-dominance near-monoculture (undesired) or a diverse mix of many species (desired), or whether it converges toward structural uniformity (undesired) or diverges into a highly patchy environment that can accommodate the habitat needs of many species (desired).

Interruption of regularly recurring fire has been identified as the main cause of diminishing native plant species diversity in Midwestern prairie remnants (Leach and Givnish 1996) and almost certainly caused the loss of more than 99% of the land area in native grasslands and meadows from within the present-day borders of Pennsylvania soon after European contact. However, fire is not the only option for grassland and meadow reclamation. Fire, mowing, mowed biomass removal, soil organic matter removal, selective weed control and livestock grazing all have a place in achieving and maintaining desired conditions at VAFO (discussed further in *Conclusion*, pp. 106–108, and Appendix G, pp. 257–261).

Measures of success in applying disturbance regimes to achieve and sustain grassland and meadow desired conditions are the same as those relating to plant species diversity and composition (p. 89).

Selective herbivory associated with long-term deer overabundance is unlike disturbances listed in the preceding paragraphs in at least two ways: its source is the target of an active reduction effort—the park's deer management program; and herbivory by deer can be both a stressor (see Table 27, pp. 86-87) and a benefit to desired conditions depending on deer density. Indicators are useful as a way of tracking success in ongoing management of the deer population and determining when adjustments are needed to attain desired condition goals. However, devising an effective set of metrics is complicated by the need to separate deer effects from the multitude of other influences on vegetation and by the fact that deer feeding preferences are notoriously variable from place to place and at different times.

> Food preferences depend partly on what is available to eat. Food variety and availability in turn depend on current local deer density, recent trends in local deer density, availability of alternative forage, human land-use patterns, forest disturbance history, snow cover, and various other factors. Thus, preferred species frequently differ between regions in the same forest type, within regions over long periods of time, at different times during a growing season, and at different deer densities in the same forest type. [Latham et al. 2005, p. 51]

Separating deer effects from other influences requires that indicators be measured using exactly the same methods inside and outside of fenced deer exclosures. The unpredictability of feeding preferences is sidestepped as a potential confounding factor in the same way, by comparing vegetation change over time between adjacent fenced and unfenced monitoring plots. Indicators related to deer herbivory include:

- relative frequencies and abundances of plants preferred and avoided by deer as food
- survival and fecundity of species known to be exceptionally highly preferred

A network of permanent deer exclosures in VAFO grasslands and meadows is crucial to monitoring these indicators. There is no other way to separate the effects of deer from the myriad other effects on plant relative abundance, survival and fecundity. The only practical way of monitoring deer effects on highly vulnerable (preferred) plant species is to plant them as greenhouse-reared plugs in identical phytometer arrays positioned in pairs—an array inside each deer exclosure and a matching one in like conditions just outside each exclosure (Latham et al. 2009). Special care will need to be taken that all routine grassland/meadow management is the same inside each exclosure as in its adjacent unfenced comparison area (management methods are discussed in the concluding section). Exclosure fences that are easily disassembled and reassembled would be ideal for this reason. The area within each exclosure should be, at minimum, 100 m^2 (1,100 sq. ft.) to enable the fence to contain an entire 25-m^2 (270-sq. ft.) monitoring plot with an adequate buffer zone (2.5 m/8 ft. wide) to minimize edge effects. Ideally at least 10 of the 175 existing 5-m × 5-m grassland/meadow monitoring plots should be paired with a new, adjacent monitoring plot of the same size surrounded by a deer exclosure fence.

5.4.2 Soil dynamics

As reclaimed grasslands and meadows mature, there should be a desired gradual shift of some soil nutrients now in labile forms in the soil into living biomass and more-recalcitrant litter (including charcoal), which binds up some of the total soil nutrient pool for long periods. In fields with residual soil modification from years of cultivation, available soil nitrogen and soil pH are likely to decrease. The rate of soil erosion also is expected to decline, as perennial root biomass, total soil organic matter and recalcitrance of soil organic matter all increase. The seemingly paradoxical decrease in available nutrients coupled with an increase in soil organic matter is explained by the higher decay resistance of litter from native perennial warm-season grasses compared with the litter of the mostly nonnative plants that dominate at present.

Metrics relating to plant species diversity and composition should reflect these shifts, including increased native grassland/meadow species richness, evenness and percentage of total plant cover, decreased overall plant density, and increased proportion of patches dominated by species of low stature.

5.4.3 Ecological resilience

"The ability of a system to absorb disturbance and still retain its basic function and structure" is a general definition of resilience (Walker and Salt 2006, p. 1). Ecologists commonly use the term resilience with two more-restricted meanings. One is the speed at which an ecosystem returns to its former state after it has been displaced from that state by a disturbance; the other is the amount of disturbance required to push an ecosystem over a threshold onto a successional pathway leading to different persistent state (Eckert 2009). The former lends itself to measurement.

Resilience has no separate metrics from those listed in Table 29 (next page). Instead, its measure is the speed of recovery among all of those metrics following severe droughts or other major perturbations.

5.5 Metrics of Ecosystem Condition—the Phytometer Approach

Because plants are the dominant organisms in nearly all non-aquatic ecosystems, their performance is an effective proxy for most aspects of whole-ecosystem condition. Plants and plant communities have been used as ecological measuring instruments since nearly a century ago (Clements and Goldsmith 1924). Phytometers remain one of the most effective and efficient ways of tracking the complexities of ecosystem conditions and dynamics.

Using selected attributes of individual plants, populations or entire communities as assessment tools in ecological research and monitoring is based on the idea that plant responses integrate a multitude of physical, chemical and other environmental factors and their complex interactions. When measured or counted at regular intervals they can better reflect ecosystem conditions and be more predictive of trends than direct measurements of abiotic factors, whose interactive effects on ecosystem components are often poorly understood. Measuring phytometers takes the place of guessing which environmental factors are important, how they rank relative to each other, and in what intricate ways they may counteract or intensify each other's effects. Most of the indicators recommended in this report are phytometric (Table 29).

Attributes of animal populations also can be important indicators of ecosystem conditions, but in many cases—especially in ecosystems on land—they are much more difficult, expensive and time-consuming to count or measure. Unlike plants, animals rarely submit docilely to measurement or stay in the same place until the next monitoring occasion. Fortunately, unlike the majority of animal species, grassland birds and butterflies are conspicuous and diurnal and some bird-related attributes may be monitored by sound as well as sight. Several animal metrics are recommended (Table 29).

In some monitoring situations it is essential to include metrics of one or more physical, chemical or other abiotic factors, in particular where such a factor has a strong effect and is likely to undergo rapid change. That is more often true of aquatic ecosystems than those on land; for instance, in streams and lakes certain water chemistry attributes can change quickly and such change can bring about massive changes in species composition and other ecosystem conditions. At present, no abiotic metric is considered to be essential for effective monitoring of ecosystem conditions in VAFO grasslands and meadows. Unforeseen circumstances could change that state of affairs at some future time.

Table 29. **Desired conditions, metrics, target values and existing conditions of grasslands and meadows in Valley Forge National Historical Park.** See footnote in Table 18 (pp. 49-51) and last page of Table 21 (p. 60) for meanings of codes in parentheses after species names.

desired condition	metric (= indicator)	target values		present condition
GRASSLAND/MEADOW PLANT COMMUNITIES AND LANDSCAPE				
Dominance by native herbaceous grassland/meadow plant species in all patches	Average percent of total plant cover in native grassland/ meadow species per 5-m × 5-m monitoring plot (100 × sum of percent cover of those species ÷ sum of all species)	EXCELLENT GOOD FAIR POOR	90%–100% 80%–89.9% 70%–79.9% < 70%	POOR 28%
High within-patch native grassland/meadow plant species diversity	Average richness (α) of native grassland/meadow plant species per 5-m × 5-m monitoring plot	EXCELLENT GOOD FAIR POOR	≥ 20 15–19.9 10–15.9 < 10	POOR 8.5
	Average evenness ($E_{1/D}$) of all plant species per 5-m × 5-m monitoring plot	EXCELLENT GOOD FAIR POOR	30–100 24–29.9 18–23.9 < 18	GOOD 24.8
	Upper quartile of evenness of all plant species per 5-m × 5-m monitoring plot	EXCELLENT GOOD FAIR POOR	36–100 30–35.9 24–29.9 < 24	GOOD 31.6
High between-patch diversity in native grassland/meadow plant species composition and identity of dominant species	Native herbaceous grassland/meadow plant species turnover (β_H) among 5-m × 5-m monitoring plots	EXCELLENT GOOD FAIR POOR	15–100 12–14.9 9–11.9 < 9	POOR 2.9
	Upper quartile of native grassland/meadow plant species richness per 5-m × 5-m monitoring plot	EXCELLENT GOOD FAIR POOR	≥ 25 20–24.9 15–19.9 < 15	POOR 11
Co-dominance by a mixture of native perennial grasses (C_4 and C_3) in a plurality of patches	Percent of 5-m × 5-m monitoring plots with > 50% aggregate cover of native perennial grasses	EXCELLENT GOOD FAIR POOR	50%–60% 40%–40.9% or 60.1%–70% 30%–39.9% or 70.1%–80% < 30% or > 80%	POOR 6.9%

Table 29 (continued)

desired condition	metric (= indicator)	target values		present condition
(grass co-dominance continued)	Average richness (α) of native perennial grass species among those monitoring plots	EXCELLENT GOOD FAIR POOR	≥ 5 4–4.9 3–3.9 ≤ 3	EXCELLENT 5.4
Co-dominance by a mixture of native grassland/meadow forbs in a substantial minority of patches	Percent of 5-m × 5-m monitoring plots with > 50% aggregate cover of native grassland/meadow forbs	EXCELLENT GOOD FAIR POOR	40%–50% 30%–30.9% or 50.1%–60% 20%–20.9% or 60.1%–70% < 20% or > 70%	POOR 3.4%
	Average richness (α) of native grassland/meadow forb species among those monitoring plots	EXCELLENT GOOD FAIR POOR	≥ 12 9–11.9 6–8.9 < 6	FAIR 7.7
Herbivory by white-tailed deer at a level that does not depress diversity of grassland/meadow forbs	Average $\alpha_E - \alpha_A$ as a percentage of α_E, where α_E = grassland/meadow species richness per fenced deer exclosure plot and α_A = grassland/meadow species richness in adjacent monitoring plot	EXCELLENT GOOD FAIR POOR	≤ 5% 5.1%–10% 10.1%–15% > 15%	not yet measured
	Average $E_E - E_A$ as a percentage of E_E, where E_E = grassland/meadow species evenness per fenced deer exclosure plot and E_A = grassland/meadow species evenness in adjacent monitoring plot	EXCELLENT GOOD FAIR POOR	≤ 5% 5.1%–10% 10.1%–15% > 15%	not yet measured
Herbivory by white-tailed deer at a level that allows population viability of highly preferred forb species	Average $S_E - S_A$ as a percentage of S_E, where S_E = percent survival of planted phytometers per fenced deer exclosure plot and S_A = percent survival of planted phytometers in adjacent monitoring plot[1]	EXCELLENT GOOD FAIR POOR	≤ 5% 5.1%–10% 10.1%–15% > 15%	not yet measured
	Average $F_E - F_A$ as a percentage of F_E, where F_E = fruit production (or other seed set index) of planted phytometers per fenced deer exclosure plot and F_A = fruit production of planted phytometers in adjacent monitoring plot[2]	EXCELLENT GOOD FAIR POOR	≤ 5% 5.1%–10% 10.1%–15% > 15%	not yet measured

[1] Percent survival of planted phytometers = 100 × count of tufts, stems or root crowns (depending on the species' growth form) ÷ the number of individuals originally planted. Value can exceed 100% if phytometer species produces offspring within the plot, either vegetatively or by seed.

[2] Time-efficient estimation of fecundity involves different methods for different species, depending on reproductive morphology. Indices can range from counts of mature fruits for large-fruited species to counts of mature fruiting heads, fruiting branches, fruiting stems or fruiting tufts of stems for small-fruited species.

desired condition	metric (= indicator)	target values		present condition
GRASSLAND-INTERIOR BIRD HABITAT				
High grassland/meadow contiguity	Total area of grasslands and meadows (excluding frequently mowed turf) greater than 50 m (160 ft.) from any tree over 5 m (16 ft.) tall, measured by GIS buffering of polygon edges based on high-resolution satellite imagery	EXCELLENT GOOD FAIR POOR	≥ 450 ha (≥ 1,100 acres) 300–449 ha (740–1,099 acres) 150–299 ha (370–739 acres) < 150 ha (< 370 acres)	unknown
Diverse mixture of patches dominated by short grasses and forbs and patches dominated by intermediate to tall grasses and forbs	Lower quartile of average relative height of herbaceous native grassland/meadow species weighted by percent cover	EXCELLENT GOOD FAIR POOR	≤ 2.25 2.26–2.5 2.51–2.75 > 2.75	POOR 3.22
	Upper quartile of average relative height of herbaceous native grassland/meadow species weighted by percent cover	EXCELLENT GOOD FAIR POOR	≥ 3.25 3.01–3.25 2.75–3 < 2.75	EXCELLENT 3.83
Substantial areas of sparse vegetation and bare ground within patches dominated by short grasses and forbs	Lower quartile of total plant species percent cover per plot (index of vegetation density)	EXCELLENT GOOD FAIR POOR	≤ 100% 100.1%–115% 115.1%–130% > 130%	POOR 146%
	Percent of plots with total plant species cover less than 100% (index of bare ground coverage)	EXCELLENT GOOD FAIR POOR	40%–60% 30%–39.9% or 60.1%–70% 20%–29.9% or 70.1%–80% < 20% or > 80%	POOR 0.03%
	Average difference between total plant species cover per plot and 100%, in plots with total plant species cover less than 100% (index of bare ground coverage)	EXCELLENT GOOD FAIR POOR	30%–40% 20%–29.9% or 40.1%–50% 10%–19.9% or 50.1%–60% < 10% or > 60%	FAIR 10.3%

(Table continued on next page.)

Table 29 (continued)

desired condition	metric (= indicator)	target values		present condition
Sparsely scattered shrubs in grasslands and meadows	Percent of plots with 0% native grassland/meadow shrub or small tree species cover (species in Appendices D and E)	EXCELLENT GOOD FAIR POOR	< 40% 40.1%–50% 50.1%–60% > 60%	POOR 92.0%
	Percent of plots with 0.1%–10% native grassland/meadow shrub or small tree species cover	EXCELLENT GOOD FAIR	40%–60% 30%–39.9% or 60.1%–70% < 30% or > 70%	FAIR 6.3%
	Percent of plots with 10.1%–25% native grassland/meadow shrub or small tree species cover	EXCELLENT GOOD FAIR	10%–15% 5%–9.9% or 15.1%–20% < 5% or > 20%	FAIR 0.6%
	Percent of plots with > 25% native grassland/meadow shrub or small tree species cover	EXCELLENT GOOD FAIR POOR	< 5% 5.1%–10% 10.1%–15% > 15%	EXCELLENT 1.1%
BUTTERFLY HABITAT				
Continuity of overall nectar abundance throughout the growing season	Lowest of 3 annual median estimated numbers of flowering stems per plot of nectar-producing plants most frequented by butterflies: (1) late May–early June, (2) mid-July, (3) late August–early September	EXCELLENT GOOD FAIR POOR	≥ 100 50–99 25–49 < 25	not yet measured
Abundance of violets (10 *Viola* taxa listed in Appendix D)—larval host plants for regal fritillary (G3/S1) and other fritillaries	Frequency (percent of plots where present)	EXCELLENT GOOD FAIR POOR	≥ 30% 25%–29.9% 20%–24.9% < 20%	FAIR 21.7%
	Average percent cover per plot over all plots	EXCELLENT GOOD FAIR POOR	≥ 0.90% 0.65%–0.899% 0.40%–0.649% < 0.40%	FAIR 0.49%

desired condition	metric (= indicator)	target values		present condition
Abundance of native thistles (5 *Cirsium* species listed in Appendices D and E)—key nectar plants for regal fritillary (G3/S1) and many other species	Frequency (percent of plots where present)	EXCELLENT GOOD FAIR POOR	≥ 15% 10%–14.9% 5%–9.9% < 5%	FAIR 9.1%
	Average percent cover per plot over all plots	EXCELLENT GOOD FAIR POOR	≥ 1.2% 0.8%–1.19% 0.5%–0.79% < 0.5%	EXCELLENT 2.81%
Abundance of milkweeds (10 *Asclepias* species listed in Appendices D and E)—key nectar plants for regal fritillary (G3/S1) and many other species	Frequency (percent of plots where present)	EXCELLENT GOOD FAIR POOR	≥ 35% 30%–34.9% 25%–29.9% < 25%	EXCELLENT 42.9%
	Average percent cover per plot over all plots	EXCELLENT GOOD FAIR POOR	≥ 3.5% 2.5%–3.49% 1.5%–2.49% < 1.5%	EXCELLENT 8.97%
Abundance of ragworts (4 *Packera* species listed in Appendices D and E)—larval host plants for northern metalmark (G3/S1S2)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT GOOD FAIR POOR	≥ 6 4–5 3 1–2	POOR (species absent or nearly so)
	Estimated total number of stems in park	EXCELLENT GOOD FAIR POOR	≥ 10,000 1,000–9,999 100–999 < 100	
Abundance of blue lupine (PR; recorded historically in park)—larval host plant for frosted elfin (G3/S1S2)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT GOOD FAIR POOR	≥ 6 4–5 3 1–2	POOR (species absent or nearly so)
	Estimated total number of stems in park	EXCELLENT GOOD FAIR POOR	≥ 10,000 1,000–9,999 100–999 < 100	

(Table continued on next page.)

Table 29 (continued)

desired condition	metric (= indicator)	target values		present condition
Abundance of wild indigo (recorded historically in park)—larval host plant for frosted elfin (G3/S1S2)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT GOOD FAIR POOR	≥ 6 4–5 3 1–2	POOR (species absent or nearly so)
	Estimated total number of stems in park	EXCELLENT GOOD FAIR POOR	≥ 10,000 1,000–9,999 100–999 < 100	
Abundance of New Jersey tea (SP)—larval host plant for mottled duskywing (G3G4/SH)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT GOOD FAIR POOR	≥ 6 4–5 3 1–2	POOR (species absent or nearly so)
	Estimated total number of stems in park	EXCELLENT GOOD FAIR POOR	≥ 10,000 1,000–9,999 100–999 < 100	
GRASSLAND/MEADOW PLANT SPECIES OF CONSERVATION CONCERN				
Secure population status of bushy bluestem (PR)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT GOOD FAIR POOR	≥ 4 3 2 1	
	Estimated total number of tufts in park	EXCELLENT GOOD FAIR POOR	≥ 10,000 1,000–9,999 100–999 < 100	
Secure population status of Elliott's beardgrass (PR)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT GOOD FAIR POOR	≥ 4 3 2 1	
	Estimated total number of tufts in park	EXCELLENT GOOD FAIR POOR	≥ 10,000 1,000–9,999 100–999 < 100	

desired condition	metric (= indicator)	target values		present condition
Secure population status of slender three-awn (TU)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of stems in park	EXCELLENT	≥ 100,000	
		GOOD	10,000–99,999	
		FAIR	1,000–9,999	
		POOR	< 1,000	
Secure population status of soft fox sedge (SP)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of tufts in park	EXCELLENT	≥ 10,000	
		GOOD	1,000–9,999	
		FAIR	100–999	
		POOR	< 100	
Secure population status of Leavenworth’s sedge (SP)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of tufts in park	EXCELLENT	≥ 10,000	
		GOOD	1,000–9,999	
		FAIR	100–999	
		POOR	< 100	
Secure population status of blue mistflower (SP)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of stems in park	EXCELLENT	≥ 10,000	
		GOOD	1,000–9,999	
		FAIR	100–999	
		POOR	< 100	

(Table continued on next page.)

Table 29 (continued)

desired condition	metric (= indicator)	target values		present condition
Secure population status of slender crabgrass (SP)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of stems in park	EXCELLENT	≥ 100,000	
		GOOD	10,000–99,999	
		FAIR	1,000–9,999	
		POOR	< 1,000	
Secure population status of St. Andrew's-cross (PT)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of stems in park	EXCELLENT	≥ 1,000	
		GOOD	100–999	
		FAIR	10–99	
		POOR	< 10	
Secure population status of narrow-leaved bush-clover (PE)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of stems in park	EXCELLENT	≥ 10,000	
		GOOD	1,000–9,999	
		FAIR	100–999	
		POOR	< 100	
Secure population status of water smartweed (SP)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of stems in park	EXCELLENT	≥ 10,000	
		GOOD	1,000–9,999	
		FAIR	100–999	
		POOR	< 100	

desired condition	metric (= indicator)	target values		present condition
Secure population status of sand blackberry (PE)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of root crowns in park	EXCELLENT	≥ 1,000	
		GOOD	100–999	
		FAIR	10–99	
		POOR	< 10	
Secure population status of branching bur-reed (PE)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of stems in park	EXCELLENT	≥ 1,000	
		GOOD	100–999	
		FAIR	10–99	
		POOR	< 10	
Secure population status of gammagrass (PE) (NOTE: Occurrence in the park may not be a locally indigenous population; needs investigation.)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of tufts in park	EXCELLENT	≥ 10,000	
		GOOD	1,000–9,999	
		FAIR	100–999	
		POOR	< 100	
Secure population status of Appalachian ironweed (PE)	Discrete clusters (at least 150 m/490 ft. apart) in park	EXCELLENT	≥ 4	
		GOOD	3	
		FAIR	2	
		POOR	1	
	Estimated total number of stems in park	EXCELLENT	≥ 10,000	
		GOOD	1,000–9,999	
		FAIR	100–999	
		POOR	< 100	

(Table continued on next page.)

Table 29 (continued)

desired condition	metric (= indicator)	target values	present condition
GRASSLAND/MEADOW ANIMAL SPECIES OF CONSERVATION CONCERN			
Secure breeding status of bobolink	Verified nesting pairs in park	EXCELLENT ≥ 15 GOOD 10–14 FAIR 5–9 POOR < 5	
	Variation in number of verified nesting pairs from average over previous 3 years (short-term population stability)	EXCELLENT < 10% decline GOOD 10%–14.9% decline FAIR 15%–19.9% decline POOR ≥ 20% decline	
	Variation in number of verified nesting pairs from average over previous 15 years (long-term population stability)	EXCELLENT ≤ 0% decline GOOD 0.1%–5% decline FAIR 5.1%–10% decline POOR > 10% decline	
Secure breeding status of eastern meadowlark	Verified nesting pairs in park	EXCELLENT ≥ 15 GOOD 10–14 FAIR 5–9 POOR < 5	
	Variation in number of verified nesting pairs from average over previous 3 years (short-term population stability)	EXCELLENT < 10% decline GOOD 10%–14.9% decline FAIR 15%–19.9% decline POOR ≥ 20% decline	
	Variation in number of verified nesting pairs from average over previous 15 years (long-term population stability)	EXCELLENT ≤ 0% decline GOOD 0.1%–5% decline FAIR 5.1%–10% decline POOR > 10% decline	
ECOSYSTEM RESILIENCE			
Relatively rapid recovery of all or nearly all indicators (above) following severe drought or other major disturbance	Speed of recovery of each indicator after park-wide disturbance severe enough to cause degradation of at least 50% of indicators	EXCELLENT ≤ 2 years GOOD 3–4 years FAIR 5–6 years POOR > 6 years	must be measured long-term

6 Conclusion: Achieving and Sustaining Desired Conditions

6.1 Present Conditions Compared with Desired Conditions

Present conditions in VAFO grasslands and meadows span the gamut of quality ratings, from poor to excellent, among the metrics (Table 29), but for the most part the gap between present and desired conditions is wide. A few indicators rank present conditions as excellent. Average within-patch richness of native perennial grass species is high. There is very little area with undesired heavy shrub cover. Average cover of native thistles and milkweeds (key butterfly food plants) and between-patch frequency of milkweeds are all high. The diversity of patches as indicated by dominant plant species' height is high across the medium to tall end of the scale.

By two indicators, present conditions are rated good: average within-patch overall species evenness and the spread among patches of evenness values at the high end of the scale. Metrics where present conditions fall in the fair range are average within-patch richness of native meadow forb species, between-patch frequency of violets and native thistles (key butterfly food plants), within-patch average cover of violets, amount of area with sparse to intermediate shrub cover, and one of several indices of the relative amount of sparse vegetation and bare ground, which are crucial for some grassland-interior birds and many native grassland/meadow plants, including several species of special conservation concern.

The majority of indicators rate present conditions in the park's grasslands and meadows as poor. The total area dominated by native herbaceous grassland/meadow plant species is low, as is average within-patch overall native grassland/meadow plant species richness. Diversity between patches in native grassland/meadow plant species composition and in which species are dominant is low. The area dominated either by native perennial grasses (grasslands) or by native meadow forbs (meadows) falls well short of the desired proportions. The diversity of patches according to the height of the dominant plant species is very low across the short-stature end of the scale. By two indices, the amount of sparse vegetation and bare ground is lacking. Across most of the grassland/meadow area there are no sparsely scattered shrubs, an important habitat component for most grassland-interior birds. Several key butterfly food sources that were present historically in or near the park are absent or nearly so, including several ragworts, blue lupine, wild indigo and New Jersey tea.

The present status of several indicators is unknown because the data have not yet been collected. These include the legacy effects of prolonged white-tailed deer superabundance on the ecological integrity of grasslands and meadows, grassland/meadow contiguity (the inverse of fragmentation), continuity of overall nectar abundance for butterflies and other nectar-feeders throughout the growing season, and resilience of all indicators following major drought or other park-wide perturbation.

Several metrics are denoted by placeholders in Table 29 because they are contingent on hypothetical future events. They involve the population status of species of special conservation concern or special habitat value that are not known to be present in the park now, but are considered significantly likely to colonize on their own as habitat conditions improve or are desired or potential targets for translocation. Translocation candidates include imperiled species whose security depends on assisted colonization because of habitat decline and fragmentation or climate change. An example is the globally imperiled regal fritillary butterfly, whose continued existence in eastern North America hinges on reestablishing populations at those few remaining sites where suitable habitat is feasible to create and maintain.

Not all desired conditions are encapsulated in the metrics presented in Table 29. For instance, a key desired condition is that most or all of native grassland/meadow plants should be of locally indigenous genotypes. However, it is impractical at this time to conduct molecular-genetic testing of every species throughout the park and in seed stock destined for planting, much less undertake the large amount of new genetic research that would be required to identify markers to reliably distinguish exotic from local genotypes. In such cases, strict adherence to a set of management principles is crucial. Even though not tested directly by routine monitoring, such desired conditions are as vital as those whose indicators are tracked as part of the adaptive management cycle.

6.2 Probable Trajectory of Grasslands and Meadows with No Change in Management

Assuming continued management by annual mowing and leaving mown biomass in place, many of the park's grasslands and meadows would in all likelihood experience steadily increasing cover by invasive plants to some percentage of total cover higher than the present 68%. This would bring about a further decrease in habitat value for native grassland/ meadow wildlife species, primarily due to the cascade of trophic effects brought on by decreased native insect diversity and biomass. Deteriorating habitat would attract few or no new arrivals among grassland/meadow bird and butterfly species of special conservation concern and existing populations in the park would likely decline. Many native grassland/ meadow plant species now present would persist, but species richness and population numbers would decrease.

A few small areas with low soil nutrient availability or thin drought-prone soils would continue to support a high proportion of native plant cover. On such exceptional sites, native perennial warm-season grasses might eventually gain ground relative to invasive nonnative species. If achieved, dominance by these warm-season grasses under continued annual mowing without biomass removal would be an impediment to colonization or persistence by members of other native grassland/meadow plant groups, including forbs, sedges, rushes and cool-season grasses, partly due to the inhibitory effects of thatch.

Continuation of the present policy of taking special stewardship action to maintain the existing stands of plants of special conservation concern would most likely lead to their persistence as small populations for some time. However, scarcity of suitable habitat elsewhere in the park would limit potential increases in population size and establishment of widely distributed multiple stands to the degree necessary to assure long-term viability.

6.3 Restoration and Adaptive Management of Grasslands and Meadows

Adaptive management, in simplest terms, consists of implementing a set of actions, monitoring the results, reconsidering the methods in light of those results, and adjusting methods in the next round of implementation accordingly. It is the only management approach that can truly be said to be science-based, because it incorporates the scientific method to continually test methods' effectiveness under a park's or other management unit's unique set of conditions and either discard or improve management protocols that prove ineffective.

The most effective grassland/meadow restoration and management methods are those that set the stage for nature to do most of the work. An agricultural paradigm, with native plant mixtures and wildlife habitat elements viewed as "crops" requiring intensive energy input every year for the foreseeable future, is unrealistic at any scale larger than a small garden or ornamental planting. For instance, relying on such methods as broadcast herbiciding, plowing, seeding and repeated herbicide application to combat invasive species may be a losing proposition where soils have been altered by centuries of cultivation. Instead, taking steps to bring about a gradual reduction in soil nutrient availability to pre-agricultural levels will get at the root of the problem by taking away invasive species' competitive advantage over native grassland/meadow plants. This may involve intensive labor, especially at first and sporadically thereafter, using methods such as biomass harvest, high-intensity prescribed burning, soil scarification, organic matter removal and recruiting the help of soil microbes by adding a carbon source. However, such an approach is likely to be more efficient in the long term than aspiring to lasting change by treating symptoms rather than underlying causes.

To create and sustain desired conditions, historical disturbance regimes are a good place to begin as models on which to base management methods. It is a worthwhile exercise to consider the similarities and differences between historical disturbances and available management methods and examine their significance in reference to desired conditions.

For example, even though little is known of the details of Native American burning practices in the Mid-Atlantic Region in the late prehistoric period and even less about how landscape burning practices evolved over thousands of years before then, we can confidently deduce from the available evidence that Indian burning was highly variable in intensity and severity, in contrast to the narrow range of variability—due to safety considerations—of modern-day prescribed burning. Similarly, the ways in which grazing and browsing differ in their ecosystem effects from mowing include herbivores' selective feeding preferences, their tendency to feed, trample, wallow and bed down more in some patches than in others, and their removal of biomass and conversion into relatively minuscule, spatially discrete manure piles, in contrast to mowing's lack of selectivity, spatial uniformity and either deposition of an even cover of thatch or full removal of mown biomass.

Restoration and adaptive management approaches consistent with desired conditions are discussed further in Appendix H, under the subject headings:

- simulating effects of historical disturbance regimes
- species augmentation and translocation
- reducing soil nutrient availability
- reducing grassland/meadow fragmentation
- native species prioritization

Glossary

Note: Terms in *italics* (except for scientific names) are defined elsewhere in the glossary.

adventive (of a species): Locally established outside its native range.

annual (plant): Usually completes its entire life cycle, seed to seed, in one year.

biennial (plant): Usually completes its entire life cycle, seed to seed, in two years.

biological diversity (or **biodiversity)**: Variety of life forms at all scales—genomes and locally adapted populations within species; species within patches, communities, landscapes and regions; habitat structure within patches and communities; patch types within communities and landscapes; community types within landscapes and regions, and ecoregions within the biosphere. (See also *habitat diversity*, *patch diversity*, *species diversity*, *structural diversity*.)

browse: Woody plant parts available for *browsing* (e.g., for white-tailed deer, consists mainly of tree and shrub twigs).

browser: Herbivore that subsists mainly by *browsing*.

browsing: Eating woody plants.

C_3: See *cool-season grass*.

C_4: See *warm-season grass*.

calcareous (of soil): Having a high calcium content, usually because derived from limestone or dolomite.

calciphile: Plant species that is partly or wholly restricted to calcareous soils.

canopy (layer): Uppermost layer of plants in a *community*, i.e., the plants forming a continuous "surface" of leaves and branches not shaded by any taller plants. In terrestrial (non-aquatic) communities, includes but is not necessarily limited to the *dominant species*.

co-dominance: *Dominance* by two to several species that are similar to one another in abundance within a community, in contrast to dominance by a single species.

community: Group of interacting plants, animals, fungi and other organisms inhabiting a given area. (See also *ecosystem*.)

community type: Named category of community based on a set of *dominant* or *indicator species* that recurs in approximately the same combination in many different places.

congener: Member of the same genus.

cool-season grass: Grass species that has photosynthetic machinery like most other kinds of plants, a system called C_3 for short, after the three-carbon molecule that is the first product of photosynthesis. Cool-season grasses usually flower and fruit in spring or early summer and grow best during spring and fall. (See also *warm-season grass*.)

cover: Two meanings—**1.** Amount of ground surface shaded by plants' leaves. **2.** Places for animals to hide from predators (usually refers to vegetation).

desired conditions: Measurable, quantitative descriptions of the states of various resources that will indicate success in achieving management goals, including *restoration* and maintenance of *ecological integrity*. They include a range of target values for each *metric* or indicator and key factors in maintaining resources within those ranges. They are usually based on pre-European-settlement conditions, taking into account constraints imposed by subsequent changes such as species extinction and extirpation, habitat fragmentation and isolation, soil modification, and introduction of *nonnative* organisms.

detrended correspondence analysis (DCA): One of several *ordination* methods applied to a matrix of presence-absence or abundance data arranged as lists of species recorded at a number of sampled locations, to determine a smaller set of synthetic variables that could help reveal patterns in species distribution. The synthetic variables are referred to as axis 1, axis 2, etc., in rank order by *eigenvalue*.

disturbance: Relatively discrete event in time that changes resources or the physical environment and typically reduces one or more populations in the affected area, opening up space for colonization by the same or different species. The spatial scale of disturbances is highly variable, from a small patch to a region.

diversity: See *biological diversity, habitat diversity*, *patch diversity*, *species diversity*, *structural diversity.*

dominance: Extent to which one or a few species dominate a community, i.e., have a majority share of total ecosystem biomass or cover. The inverse of *evenness*.

dominant species: Organism that exerts strong control over environmental conditions by virtue of high population density or majority share of total ecosystem biomass. (See also *keystone species*.)

dwarf shrub: Shrub species that typically grows no taller than 1 m (3 ft.), e.g., lowbush blueberries (*Vaccinium angustifolium*, *V. pallidum*), black huckleberry (*Gaylussacia baccata*), bush-honeysuckle (*Diervilla lonicera*), pasture rose (*Rosa carolina*), hardback (*Spiraea tomentosa*).

ecological integrity: Ability of an *ecosystem* to support and maintain a *community* of organisms with species composition, *diversity* and functional organization comparable to those with the smallest degree of post-European-settlement human influence. "An ecological system or species has integrity … when its dominant ecological characteristics (e.g., elements of composition, structure, function and ecological processes) occur within their natural ranges of variation and can withstand and recover from most perturbations imposed by natural environmental dynamics or human disruptions" (Eckert 2009). Sometimes called ecosystem "health" or the quality of being "natural."

ecological resilience: Three intertwined and somewhat interchangeable meanings—**1**. "Ability of a[n eco]system to absorb disturbance and still retain its basic function and structure" (Walker and Salt 2006, p. 1). **2**. The speed at which an ecosystem returns to its former state after it has been displaced from that state by a disturbance. **3**. The amount of disturbance required to push an ecosystem over a threshold onto a successional pathway leading to different persistent state.

ecosystem: A *community* and its physical environment.

ecosystem engineer: See *keystone species*.

eigenvalue: The proportion of the variance in a species-by-sample-location matrix accounted for by each axis derived using an *ordination* method such as *detrended correspondence analysis*. Axes are ordered by eigenvalue rank, i.e., the first axis has the highest eigenvalue, the second has the next-highest, etc.

evenness: Measure of how similar in abundance co-occurring species are within a patch or community. The inverse of *dominance*. One component of *species diversity*. (Compare *richness*; see also *biological diversity*.)

exotic: See *nonnative.*

field: A specific area of *grassland* or *meadow* in Valley Forge National Historical Park bounded by landmarks such as forest edges, park boundaries, roads, hedgerows or park structures and identified on a map by a number or letter symbol.

forb: Herbaceous *vascular plant* that is not a grass or a grass-like plant such as a sedge or a rush. Most forbs are wildflowers, although herbaceous plants that have no flowers such as ferns are often included. (See also *graminoid.*)

forest: Area with 60% to 100% tree cover. (See also *woodland* and *savanna.*)

functional group: Subset of species in a community whose members are similar by one or more meaningful criteria (e.g., morphology, environmental response, role in ecosystem function, trophic level or taxonomic relatedness). Examples in *grasslands* and *meadows* include perennial *warm-season grasses*, *cool-season grasses*, *annuals*, nitrogen-fixers (plants that host symbiotic nitrogen-fixing microbes), *nonnatives*, *invasives*, generalist *herbivores* or birds.

generalist herbivore: Animal species that subsists on a wide variety of plant foods. (See also *specialist herbivore*.)

graminoid: Grass or grass-like plant such as a sedge or a rush. (See also *forb.*)

grassland: Area dominated by herbaceous plants with more than 50% cover by grasses that is uncultivated and has soils that are not saturated year-round. Includes prairie and grass-dominated savanna. (See also *meadow.*)

grassland bird or **grassland-interior bird**: A bird species that needs access to large, unfragmented grasslands or meadows, or to artificial habitats that supply at least some of the same nesting cues and resources, in order to nest and successfully rear young. In the Mid-Atlantic Region, 5–6-ha (12–25-acre) patches of grassland or meadow sometimes support small *sink* populations of grassland birds, 10–20-ha (25–50-acre) patches do so more consistently, and 40–100 ha (100–250 acres) or more of unbroken grassland or meadow may support *source* populations and multiple grassland bird species (Peterjohn (2006).

grassland/meadow species (or **grassland/ meadow specialist)**: Any species of plant, animal or other organism that depends for all or part of its life cycle on grassland or meadow habitat. In this document refers only to species that are *native* to the *Greater Piedmont*.

grazer: Herbivore that subsists mainly by *grazing*. Some grazers (e.g., bison) eat mainly grasses; others (e.g., white-tailed deer, which are also *browsers*) eat mainly *forbs*.

grazing: Eating herbaceous plants. (See also *browsing*.)

Greater Piedmont: All of Pennsylvania south and east of Blue Mountain except for South Mountain. Includes parts of four Level III ecoregions (Northern Piedmont, Atlantic Coastal Plain, Northeastern Highlands, Ridge and Valley) and eight Level IV ecoregions (Triassic Lowlands, Piedmont Limestone/Dolomite Lowlands, Piedmont Uplands, Diabase and Conglomerate Uplands, Delaware River Terraces and Uplands, Reading Prong, Northern Limestone/Dolomite Valleys, Northern Shale Valleys) (Woods et al. 1999a, 1999b). It is the area inhabited by a distinctive regional species pool of plants, animals and other organisms in which Valley Forge is embedded.

growth form: Classification of plants by size, shape, longevity and mode of overwintering. The main distinction is herbaceous (dies back to the ground in winter) versus woody (bears overwintering buds above the ground). Woody plants are grouped into trees, shrubs, woody vines (lianas) or creepers; they may be deciduous or evergreen. Herbaceous plants are grouped by longevity into *annuals*, *biennials*, short-lived *perennials* or long-lived perennials; by shape into *forbs* or *graminoids*; and by posture into self-standing, prostrate or climbing (herbaceous vines).

habitat: Place where a plant, animal or other organism lives. Defined relative to an individual species or a group of similar species.

habitat diversity: Measure of the difference in species composition, or turnover, among places—usually patches within a community or communities within a landscape. (See also *biological diversity* and *patch diversity*.)

herbaceous (plant): Having no woody parts aboveground. The stems of herbaceous plants in the temperate zone die back to the ground surface in winter. Includes wildflowers, grasses (except bamboos), rushes, sedges, ferns and clubmosses. (See *growth form*.)

herbarium record: *Voucher specimen* of a plant mounted on a sheet of paper labeled with notes on taxonomy, date of collection, name of collector, geographic location and often habitat information, organized and preserved in a collection for scientific reference, typically in a natural history museum. The written information may be digitized to ease retrieval.

herbivore: Animal species that subsists on plant foods.

herbivory: Eating plant parts. (See *browsing* and *grazing*.)

Holocene epoch (or **Holocene interglacial period)**: Present interglacial period, roughly the last 10,000 years. In North America, the Holocene is distinguished from the 15–20 previous interglacial periods in the *Quaternary period* by the presence and profound ecological influence of humans. (See also *Pleistocene epoch*.)

indicator: Two meanings—**1.** *Indicator species.* **2.** *Metric.*

indicator species: Two meanings—**1.** One or more species characteristic of a *community type* or related set of community types (e.g., wetlands) used to distinguish it from other communities. **2.** One or more species known to be highly responsive to direct or indirect human influences whose presence, condition or abundance are used to rate ecosystem quality or to assess adverse impacts.

integrity: See *ecological integrity*.

intensity (of fires and other disturbances): Cumulative force of an event (e.g., heat released by a wildfire, wind force and duration in a storm, or depth of inundation, flow speed and duration of a flood), regardless of the magnitude of ecological impact. Differs from *severity*.

invasive: Two meanings—**1.** Describes a *nonnative* plant, animal or other organism that undergoes extreme proliferation, partly resulting from a lack of coevolved parasites, predators, diseases and other checks on population growth outside its native range. Invasive organisms typically disrupt ecosystems by killing off or crowding out native populations, changing key environmental attributes such as resource availability, soil conditions and fire regimes, or starting a cascade effect by disrupting multispecies interactions. **2.** Sometimes also used to describe native species that undergo extreme proliferation as an unintended consequence of human activity.

keystone species (or **ecosystem engineer)**: Organism that accounts for a small (or negligible) share of ecosystem biomass but has a disproportionately powerful influence on ecosystem processes. If such a species is removed, profound changes in community composition and structure result. (See also *dominant species*.)

labile (of minerals in soil or soil organic matter): Readily made available to plants by microbial transformation or decomposition. (See also *recalcitrant*.)

landscape: Heterogeneous land area composed of multiple interacting *ecosystems* in *patches* or blending together across *gradients*, each usually repeated in similar form throughout.

liana: Woody vine.

meadow: Area dominated by herbaceous plants with more than 50% cover by *forbs* that is uncultivated and has soils that are not saturated year-round. (See also *grassland.*)

meadow specialist: See *grassland/meadow specialist*.

metapopulation: Geographically clustered group of localized populations that are genetically and dynamically connected by occasional intermigration of individuals. Often consists of multiple *sources* and *sinks*.

metric: Measurable, quantitative attribute of specific ecosystem components (e.g., plants, animals, water, soil, people) used to characterize, evaluate and communicate the condition of an ecosystem at a specific time or across a sequence of intervals. Also called indicator.

native: Describes a plant, animal or other organism spontaneously inhabiting a given region without having been introduced there deliberately or inadvertently by human activity. In regions in the Americas, often taken to mean species present at the time of first European contact, irrespective of whether they might have been introduced from other regions by human action before then. Synonymous with indigenous.

nonnative: Describes a plant, animal or other organism inhabiting a given region by virtue of having been introduced, either deliberately or inadvertently, by human activity. Synonymous with exotic and introduced. A minority of nonnative species become *invasive*.

ordination: Any of several methods of statistical analysis used in exploratory data analysis (in contrast to hypothesis testing) to order objects characterized by data values in multiple variables so that similar objects are nearer each other and dissimilar objects are farther from each other. In plant community ecology, sampled locations are treated as objects, each of which is characterized by a value for each member of the entire species pool (species are treated as variables) indicating its presence or abundance there; simultaneously, the species are treated as objects, each of which is characterized by a value for each location (locations are treated as variables) indicating its presence or abundance there. (See also *detrended correspondence analysis* and *eigenvalue*.)

patch: Relatively discrete area within a *community* or *ecosystem* that is different in some significant way from its surroundings, usually consisting of, or reflected in, differences in plant species composition.

patch diversity: Variety of patch types within a *community* or *ecosystem*. (See also *biological diversity* and *habitat diversity*.)

perennial (plant): Typically has a lifespan of three to many years. Usually applied to *herbaceous* plants.

phylogenetic: Pertaining to the evolutionary history of a group of organisms, i.e., the relationships of groups of organisms to one another by descent from common ancestors. (See also *taxon*.)

phytometer: Living plant or group of plants on which selected attributes are measured as *metrics* of ecosystem condition or dynamics. Their use in research and monitoring is based on the idea that responses of plants integrate a multitude of physical, chemical and other environmental factors and their complex interactions; thus, when measured at regular intervals they better reflect ecosystem condition and are more predictive of trends—often with less effort—than direct measurements of abiotic factors, whose interactive effects on ecosystem components are poorly understood.

Pleistocene epoch: All of the *Quaternary period* up to but not including the *Holocene epoch*, roughly from 2,000,000 to 10,000 years ago. It included 15–20 cycles of continental glaciation (ices ages) separated by relatively warm interglacial periods.

population: Group of individuals of the same species living in a given area at a given time.

prairie: Expansive *grassland* with less than 10% tree cover. (See also *savanna*.)

Quaternary period: Roughly the last 2,000,000 years to the present, a time of great climatic fluctuation with 15–20 cycles of continental glaciation (ices ages) interspersed with relatively warm interglacial periods, including the *Holocene epoch*—the present-day interglacial period.

recalcitrant (of organic matter in or on top of soil): Resistant to decomposition. (See also *labile*.)

reclamation (of grasslands and meadows): "The main objectives of reclamation include the stabilization of the terrain, assurance of public safety, aesthetic improvement, and usually a return of the land to what, within the regional context, is considered to be a useful purpose" (Society for Ecological Restoration International Science and Policy Working Group 2004). Applied to areas that may or may not have supported grasslands or meadows historically. Includes many of the same activities that constitute *restoration*.

resilience: See *ecological resilience.*

restoration (of grasslands and meadows): "An intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability" (Society for Ecological Restoration International Science and Policy Working Group 2004). Applied to remnants of long-persisting historical grasslands and meadows that have been degraded as the direct or indirect result of human activities. (See also *reclamation.*)

return interval (of fires and other disturbances): Average time between events in a given place, i.e., the inverse of frequency. Because it is an average, it does not reflect predictability, which is inversely related to how much the intervals between successive disturbances vary.

richness (of species): Number of species present in a given area (e.g., survey plot, patch, community, landscape or region). One component of *species diversity*. (Compare *evenness*; see also *biological diversity*.)

savanna: *Grassland*, *meadow* or low *shrubland* with scattered trees or tall shrubs making up between 10% and 25% of the total vegetation cover. (See also *forest* and *woodland.*)

severity (of fires and other disturbances): Impact on an ecosystem and its constituents, including organisms, resources and the physical environment. Differs from *intensity*.

shrubland: Area dominated by shrubs. Usually applied to communities that persist for relatively long periods of time (transient shrub-dominated successional stages are often called thickets). Dwarf shrubland is dominated by shrubs no taller than 1 m (3 ft.), intermediate shrubland, 1–2 m (3–6 ft.) and tall shrubland, 2–6 m (6–20 ft.). Shrubland includes savanna dominated by dwarf shrubs. (See also *dwarf shrub* and *tall shrub*.)

sink: Localized population (and its habitat) with a consistently negative growth rate, i.e., the death rate is higher than the birth rate and continued existence depends on immigration. May nonetheless be important to help sustain high overall population numbers and genetic diversity in a *metapopulation*. Occurs in smaller or lower-quality habitat areas. (See also *source*.)

source: Localized population (and its habitat) with a consistently positive growth rate, i.e., the birth rate is higher than the death rate and population stability occurs only if the emigration rate balances the surplus of births over deaths. Occurs in large areas of contiguous, high-quality habitat. (See also *metapopulation* and *sink*.)

specialist: See *grassland/meadow specialist*, *grassland bird* and *specialist herbivore*.

specialist herbivore: Animal species whose diet is restricted to only one or a narrow set of plant species. (See also *generalist herbivore*.)

species diversity: *Richness* and *evenness* of species in a given area. (See also *biological diversity.*)

species dominance: See *dominance.*

species evenness: See *evenness*.

species of special conservation concern (or **species of special concern)**: Species whose continued existence in all or a part of its native range is known to be imperiled, judged to be at risk of becoming imperiled, or undergoing sustained or rapid decline. In Pennsylvania, vascular plants, mammals, birds, snakes, lizards, turtles, amphibians, freshwater mussels, Lepidoptera (butterflies and moths), Odonata (dragonflies and damselflies) and a few species belonging to other groups of organisms are systematically tracked and an official list of species of special concern is updated yearly by the Pennsylvania Biological Survey, Pennsylvania Natural Heritage Program and state natural resource agencies.

species richness: See *richness*.

structural diversity: Variety of community *structure* present within a defined area. (See also *biological diversity*.)

structure (of a community): Vertical layering and horizontal arrangement of plants of different sizes and *growth forms*, including the extent of vegetation cover, canopy closure and bare ground, the type and abundance of dead plants or plant parts, and the amounts and types of decomposing plant material.

subordinate species: Organism present in a community at a low population density or a minority share of total ecosystem biomass relative to *dominant species.*

succession: Non-seasonal, directional and continuous pattern of colonization, relative dominance and extinction on a site by populations, usually set in motion by *disturbance*.

successional stage (or **seral stage)**: Species composition and other community attributes characteristic of an interval during succession whose beginning and end is defined by milestone events such as a shift in dominance from one species to another or from one category of species to another.

tallgrass: Used in two different ways—**1.** With "prairie," "grassland" or "species"—of or dominated by grasses that ordinarily grow taller than 1.5 m (about 5 ft.). Native grasses in the Mid-Atlantic Region in this category include Indiangrass (*Sorghastrum nutans*), big bluestem (*Andropogon gerardii*) and eastern gamma grass (*Tripsacum dactyloides*). **2.** With "meadow"—used in several reports pertaining to Valley Forge National Historical Park (National Park Service 2007; Podniesinski et al. 2005; Tiebout 2003) to signify areas dominated by herbaceous plants that are mowed no more often than once or twice a year, regardless of the height of the vegetation or whether it is *grassland* or *meadow*.

tall shrub: Shrub species that typically grows to a height of 2–6 m (6–20 ft.).

taxa: Plural of *taxon*.

taxon: Unit of *phylogenetic* classification of an organism at any level of the classification hierarchy, including (but not limited to) domain, kingdom, phylum, class, order, family, genus, species, subspecies and variety.

taxonomic: Relating to *phylogenetic* classification of organisms.

translocation: Population introduction, reintroduction or augmentation of a population, usually of a species of special concern.

VAFO: Valley Forge National Historical Park.

vascular plant: Plant in which fluids circulate via conducting vessels—xylem and phloem. All true plants are vascular plants except mosses, liverworts, hornworts and green algae (other algae and lichens are not classified as plants). Includes all trees, shrubs, vines, wildflowers, grasses, rushes, sedges, ferns, clubmosses and spikemosses (the latter are not true mosses).

vine: Vascular plant that cannot sustain an upright position by itself but climbs freestanding plants or other objects or creeps along the ground. Vines may be woody (lianas) or herbaceous, and herbaceous vines may be annual or perennial.

voucher specimen: Dried, mounted plant specimen identified and preserved for scientific reference. Part of a *herbarium record*.

warm-season grass: Grass species that has a specialized photosynthetic system called C_4 for short, after the four-carbon molecule that is the first product of photosynthesis. It works in a manner similar to a turbocharger in a car engine, delivering carbon dioxide much more efficiently (using far less water) to the sunlight-powered parts of the plants' cells that combine CO_2 with H_2O to produce sugars, fueling growth. Warm-season grasses usually flower and fruit in late summer or fall and grow mainly in the heat of summer. The C_4 system enables warm-season grasses to continue photosynthesizing and growing when most plants are forced by heat or dry soil conditions to shut down. (See also *cool-season grass*.)

woodland: Area with 25% to 60% tree cover. (See also *forest* and *savanna.*)

woody plant: Plant that does not die back to the ground in winter but bears its overwintering buds above the ground on stems and twigs of wood. Includes trees, shrubs, woody vines (lianas) and creepers (prostrate woody plants).

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Appendix A. Conservation Significance of Native Grasslands and Meadows in the Mid-Atlantic Region

Globally and Regionally Imperiled Ecosystem

Scientists conducting a global study of conservation needs recently tallied the total areas of habitat converted or destroyed and of habitat protected in all of the major ecosystem categories worldwide (Hoekstra et al. 2004). The picture is upbeat for certain ecosystems—including tundra, boreal forest and taiga, montane grassland and shrubland, and temperate conifer forest—but it is bleak for many others. Of all ecosystem types evaluated, temperate grassland is in the direst straits. For temperate grassland (including savanna) and shrubland together, the ratio of acres destroyed to acres protected is ten to one, five times higher than even the beleaguered tropical rainforest. Worldwide, only 5% of the land in temperate grassland and shrubland has been protected to date while 46% has already been destroyed. The figures are even more dismal for the eastern United States, where native grasslands have been under extreme pressure for more than 300 years and most were converted long ago to agricultural, residential, commercial and other uses.

According to one estimate from historical records, grasslands and meadows in Pennsylvania covered approximately 600–620 km^2 (230–240 square miles) around the time of European contact (Latham 2005a), just over 0.5% of the state's land area. For comparison, the estimated present-day wetland cover is 982 km^2 (379 square miles) or 0.8% (Land Cover Institute 2001). Surviving remnants of early grasslands sum to less than 2.5 km^2 (1 square mile), a 99.6% decline, which continues and is even accelerating at many sites (Latham 2005a). Other persistent, unplanted grasslands of more recent origin that are dominated by native species raise the statewide total to roughly 9 km^2 (3.5 square miles), less than 2% of the historical extent and 0.01% of the state's land area. This small area harbors a vastly disproportionate number of species of special conservation concern (Latham 2005a; Latham and Thorne 2007). Of the 294 vascular plant species classified as endangered in Pennsylvania, 112 (38%) are characteristic of grassland and meadow habitats. There are 86 species classified as threatened in the state, of which 35 (41%) live mainly in grasslands and meadows. Out of 110 vascular plant species that have been extirpated from Pennsylvania since European settlement, 38 (35%) are grassland and meadow habitat specialists. These percentages are about double the 19.5% of the state's land currently estimated to be in grassland and meadow cover[1] (Myers et al. 2000) and are vastly disproportionate to the 1% to 3% of the land within Pennsylvania's borders estimated from historical sources to have been in similar vegetation around the time of European settlement (Latham 2005a).

Pennsylvania's breeding bird fauna includes 15 species that are referred to as grassland-interior species, that is, in order to nest and successfully rear young they need access to large grasslands or meadows, or to artificial habitats that supply at least some of the same nesting cues and resources. Two are classified as endangered and five as threatened or candidates at risk and nearly all have undergone serious declines in recent decades. Several other endangered, threatened, and

[1] The sum of Myers and colleagues' "woody transitional (5% < cover of woody plant foliage < 40%), also shrubland or forest regeneration" and "perennial herbaceous (grasslands, pasture, forage, old fields < 5% shrubs)" categories, mapped by analysis of satellite photography.

declining bird, mammal, and reptile species depend on native grassland and meadow habitats. Of the Lepidoptera species classified as endangered, threatened or rare in the state, 49 (74%) of the butterfly species and 45 (38%) of the moth species are known to depend in part or wholly on grasslands or meadows because their larvae are specialist feeders on native plant host species that live predominantly in these habitats (Latham and Thorne 2007). Even higher percentages use grasslands and meadows as adults as a source of nectar.

Since the first European settlement, native grasslands and meadows have steadily declined. These plant communities were once composed of hundreds of native plant species that, for millions of years, provided the highest quality food and habitat for native grassland and meadow wildlife. The typical meadow today is an abandoned field invaded by a few introduced species—multiflora rose, autumn-olive, Japanese honeysuckle, Amur honeysuckle, Canada thistle, mile-a-minute and Japanese stilt-grass are examples—that crowd out the native plants and degrade the habitat for most native animal species by contributing little or nothing to the food web on which all native wildlife depends. Native grasslands and meadows are now rare indeed throughout the Mid-Atlantic Region and in most of the East.

Habitat for Declining and Imperiled Birds, Butterflies and Other Wildlife

When time, funds, and land are allocated to native grassland and meadow reclamation in the hopes of attracting nesting pairs of grassland-interior birds, a critical question is, will they come? There are no guarantees, but because eastern grassland birds have always depended on a habitat that is often short-lived, they have an innate ability to find and colonize new habitats that are remote from previously existing habitats. As evidence, abandoned strip mines “reclaimed” with mixtures of exotic grasses across western Pennsylvania have attracted breeding populations of Henslow’s sparrows, upland sandpipers, and other grassland birds that had nearly disappeared from the area (McWilliams and Brauning 2000; Mattice et al. 2005).

A set of concepts in ecology and population biology often invoked to help illuminate the relationship between grassland-interior birds and grassland and meadow reclamation is that of sources, sinks and ecological traps. These terms describe particular areas of contiguous habitat in a region or landscape for a particular species. A source is an area of high-quality contiguous habitat in which the population growth rate of the species of interest is positive. A sink is an area of low-quality habitat in which the population growth rate is negative. All of the individuals of a species breeding in all of the habitats within dispersal distance of each other are termed a metapopulation. If there were no source in a metapopulation’s range, it would eventually die out. Sources are essential but sinks are important also, because they allow a metapopulation to be larger and more genetically diverse than it would be if it occupied only its source habitats. Larger, more dispersed, and more genetically diverse populations are more resilient against setbacks and less vulnerable to potential catastrophes caused by unusual weather, disease outbreaks and other environmental variability. A primary goal of grassland and meadow reclamation is to provide source habitats for a variety of grassland-interior bird species. A worthy secondary goal is to expand the supply of sink habitats.

The strict definition of ecological trap is a low-quality habitat that is preferred over other available, higher-quality habitats (Donovan and Thompson 2001). It requires an inverse relationship between habitat preference and habitat quality. In computer models of populations and habitat arrays, the presence of ecological traps leads to extinction. Although inverse relationships between habitat preference and habitat quality may sometimes occur[2], analogous situations may be more common where habitat preference and habitat quality have a more complex relationship. The term ecological trap is sometimes erroneously used for habitats where cues attract nesting animals at similar (not higher) rates as to either source habitats or sink habitats, but where almost no offspring ever get out alive. A common example is a hayfield that is mowed every May, destroying any nests, eggs, and nestlings. Such a situation does not cause a metapopulation's extinction but it would certainly be a sign of failure of a grassland and meadow reclamation project.

The list of grassland and meadow wildlife species of special conservation concern is not limited to birds. Other vertebrates and a host of insects and other arthropods utilize grassland and meadow habitats, including certain butterflies, moths, dragonflies, damselflies, beetles, ants, wasps, bees, spiders, mites, and members of many other groups. Little is known about the conservation needs of most invertebrate groups but entomologists at the Pennsylvania Natural Heritage Program, Carnegie Museum of Natural History, Academy of Natural Sciences, and other institutions are actively working to remedy this situation for various critical landscapes in the state and their findings will doubtless inform grassland and meadow reclamation priorities and methods in the future.

Hundreds of species of moths and butterflies utilize the native plants of the Greater Piedmont's grasslands and meadows. Adults of a high proportion of these species feed on the nectar of grassland and meadow forbs. Most rare Lepidoptera species in the state are specialist herbivores, narrowly limited to feeding as larvae on just one or two host plant species or genera, in many cases of plants that are characteristic of grassland and meadow habitats. One hundred eighty-three Lepidoptera species (66 butterflies and 117 moths) are tracked or proposed for tracking by the Pennsylvania Natural Heritage Program and the Pennsylvania Biological Survey because they are candidates for classification as endangered or threatened in the state (J. Rawlins and B. Leppo, personal communication). Of these, 49 (74%) of the butterfly species and 45 (38%) of the moth species are known to depend in part or wholly on native grasslands and meadows because their larvae are specialist herbivores whose host plants live mainly in these habitats. Even higher percentages of Lepidoptera use native plants inhabiting grasslands and meadows as adults as a source of nectar. The larval host plants are unknown for another 50 (27%) of the rare Lepidoptera species; some of these have been captured in grasslands and other herbaceous-plant-dominated ecosystems and a subset of them is likely to depend on native plants in those habitats.

These animals have suffered declines just as grassland-interior birds and many grassland/meadow plants have. One indication of the severity of the decline is how many species have already been extirpated from the state. At least seven grassland and meadow butterflies and six moths are known to have been extirpated or are presumed extirpated from Pennsylvania. The magnitude of the risk to the remaining grassland/meadow Lepidoptera is reflected in the number of globally rare species that occur in Pennsylvania. The list includes five butterflies: the northern metalmark (*Calephelis borealis*), Persius duskywing (*Erynnis persius persius*), Appalachian grizzled skipper (*Pyrgus wyandot*), diana fritillary (*Speyeria diana*) and regal fritillary (*Speyeria idalia*) and at least twelve moths.

Key elements of grassland and meadow habitats for moths and butterflies are larval host plants, pupation sites, adult nectar sources, and adult resting sites. It is crucial to many species that a diverse array of adult nectar sources co-occur in their habitat, because adults of those species live and must

[2] A classic example is Cooper's hawks in the city of Tucson, where nesting density is much higher than in the surrounding countryside but nestling survival is lower by more than an order of magnitude, due to a disease carried by urban pigeons and doves (Boal and Mannan 1999, cited by Battin 2004).

feed for a longer period during the growing season than any one plant species is in flower. Promoting a high diversity of vascular plant species and habitat structure is a major key to benefiting moths and butterflies in grassland and meadow reclamation and management.

The specific host plants of rare Lepidoptera known to occur in the regions surrounding grassland and meadow reclamation projects are key targets for planting, monitoring, and management programs.

Carbon Sequestration

Temperate zone grasslands store as much organic carbon in tons per unit of land area as forests and much more than croplands and other agroecosystems (Gibson 2009). Transformation of grasslands into cropland originally released vast amounts of carbon into the atmosphere in a relatively short period, but the reverse process—carbon storage after abandonment of farmland—is far slower. In one study in temperate semiarid grassland the sequestration rate was estimated at 60 kg/ha/year (54 pounds/acre/year); rates are expected to be appreciably faster in the moist Mid-Atlantic Region.

Counterintuitively, prescribed burning may have a negligible net effect on carbon sequestration or even cause a net increase in immobilized carbon, despite the CO_2 released in combustion (DeLuca and Aplet 2008). Two factors are at work in this seeming paradox. First, some of the carbon becomes charcoal, which has a residence time in the soil of thousands of years, compared with tens to hundreds of years for recalcitrant organic matter. Second, repeated burning has the effect of shifting species dominance from plants that have relatively small belowground biomass and readily decomposable litter (e.g., invasive perennial C_3 grasses originally planted for livestock forage, annuals such as stiltgrass and common mugwort, and invasive vines) to native perennial C_4 grasses such as Indian-grass and little bluestem, which have massive root systems and more decay-resistant litter.

Appendix B. Eyewitness and Secondary Accounts of Historical Native Grassland and Meadow Vegetation in the Greater Piedmont

Indian burning around the Delaware Bay, 1632

Background

Captain David Pietersz de Vries (1593–1662) was a navigator from Hoorn, Holland, patroon of the company that founded the Dutch colony of Zwaanendael in 1631 at present-day Lewes, Delaware. He left the colony of about 30 residents for a return trip to Holland, during which time the man he left in charge got into a quarrel with a particular clan of Indians. Despite the efforts of other Indians to quell the dispute, it escalated until the aggrieved clan massacred the entire colony. De Vries sailed back in December 1632 to see if the colony and relations with the Native American neighbors could be salvaged.

Original text excerpts

From *A History of the Original Settlements on the Delaware, From Its Discovery by Hudson to the Colonization Under William Penn* (Ferris 1846, p. 23):

> The ensuing year, 1632, De Vries returned to the Delaware. Before leaving the Texel he had by some means heard of the melancholy end of his colony. He arrived on our coast in the early part of the winter, and long before they saw the land, knew they were near the coast, "by the odour of the under-wood, which at this time of the year is burned by the Indians, in order to be less hindered in their hunting."

From De Vries's 1655 memoir, *Korte Historiael ende Journaels Aenteyckeninge* (Myers 1912, p. 15):

> The 2d, threw the lead in fourteen fathoms, sandy bottom, and smelt the land, which gave a sweet perfume, as the wind came from the northwest, which blew off the land, and caused these sweet odors. This comes from the Indians setting fire, at this time of year, to the woods and thickets, in order to hunt; and the land is full of sweet-smelling herbs, as sassafras, which has a sweet smell.

Interpretation of text

There are many eyewitness accounts of deliberate use of fire on the landscape by Indians in many parts of the Americas, but this is one of a very few from the territory of the Lenape, the main inhabitants of southeastern Pennsylvania around the time of European contact.

Meadows and Indian cornfields along the lower Delaware River, 1634

Background

Captain Thomas Yong (1579–1636?) was an English adventurer/entrepreneur whose life's mission at age 54 became the quest for a "northwest passage" through North America from the Atlantic to the Pacific. In 1633, after petitioning for and being granted permission by King Charles I, he launched an expedition. His first hypothesis was that the Delaware River (which he named the Charles River in honor of the king) led to the Great Lakes where one or more river outlets in turn led to the "North Ocean." He may have been the first European to describe in writing the landscape and people of what is now southeastern Pennsylvania.

Original text excerpt

From "A breife Relation of a voyage lately made by me Captayne Thomas Yong, since my departure from Virginia, upon a discovery, which I humbly present to the Right Ho^{ble} Sr Francis Windebanke, knight, Principall Secretary of State to his Ma^{tie}"(Yong 1634, reprinted in Myers 1912, pp. 47, 48), describing the lands along the lower Delaware River and its major tributaries:

> The river is broad and deepe, and is not inferior to any in the North of America, and a ship of 300 Tonnes may saile up within three leagues of the rockes. … The soyle is sandy and produceth divers sorts of fruites, especially grapes, which grow wild in great quantity, of which I have eaten sixe severall sorts, some of them as good as they are ordinarilly in Italy, or Spaine... The earth being fruitefull is covered over with woods and stately timber, except only in those places, where the Indians had planted their corne. The Countrey is very well replenished, with deere and in some places store of Elkes. The low grounds of which there is great quantitie excellent for meadowes and full of Beaver and Otter. … Heere are also great store of wild hops yet excellent good and as faire as those in England …

Interpretation of text

Yong's statement verifies that his crew explored the Delaware River at least as far upstream as the falls at Trenton. The only native plants he mentioned by name—grapes and wild hops—seem to reflect a fermented beverage bias. Three items suggest open meadows: "The earth being fruitefull is covered over with woods and stately timber, except only in those places, where the Indians had planted their corne"; "The low grounds of which there is great quantitie excellent for meadowes and full of Beaver and Otter," possibly referring to meadows resulting from beaver dam abandonment; and "Heere are also great store of wild hops," referring to the eastern North American variety of common hops (*Humulus lupulus* var. *lupuloides*), a shade-intolerant herbaceous vine.

Grassland and Indian burning along the Delaware River, 1656

Background

Pehr Mårtensson Lindeström (1632–1691) was appointed engineer for the New Sweden colony in present-day Delaware, Pennsylvania and New Jersey. He embarked in 1654 on the ship Örn, spent just over a year presiding over the building of fortifications, and returned to Sweden in 1656. Years later, bedridden with illness, he wrote a memoir of his experiences in the New World.

Original text excerpt

From Pehr Lindeström's *Geographia Americae: with an account of the Delaware Indians: based on surveys and notes made in 1654–1656* (Lindeström and Johnson 1925, pp. 213-215), describing vegetation near the Delaware River and Native American use of fire in hunting:

> The soil in New Sweden is so loose, as if we stood and poked in ashes, because the earth there is not so closely rooted or sodded, as when it is somewhat used in the beginning, burnt, sown and cut. There indeed grows a great deal of high grass, which reaches above the knees of a man, but the stalks are so far apart that one can uproot it like flax or hemp. There is also no thickly grown forest but the trees stand far apart, as if they were planted. …
>
> Now as soon as the winter bids good night, they begin with their hunts, which is done with a fine innovation. Now at that time of the year the grass which grows there, as has been said, is as dry as hay. When now the sachem wants to arrange his hunt, then he commands his people [to take a position] close together in a circle of ½, 1 or 2 miles [the Swedish mile was 36,000 feet], according to the number of people at his command. In the first place each one roots up the grass in the position, [assigned to him] in the circumference, to the width of about 3 or 4 ells, so that the fire will not be able to run back, each one then beginning to set fire to the grass, which is mightily ignited, so that the fire travels away, in towards the center of the circle, which the Indians follow with great noise, and all the animals which are found within the circle, flee from the fire and the cries of the Indians, traveling away, whereby the circle through its decreasing is more and more contracted towards the center. When now the Indians have surrounded the center with a small circle, so that they mutually cannot do each other any harm, then they break loose with guns and bows on the animals which they then have been blessed with, that not one can escape and thus they get a great multitude of all kinds of animals which are found there.

Interpretation of text

This is one of the earliest accounts of grassland vegetation and burning by Lenape Indians in the Delaware Valley.

Upland grasslands or meadows inland from the Delaware River, 1683

Background

Thomas Paskell, also spelled Paschall (1634–1718), a pewterer in Bristol, England, purchased 500 acres in what is now Angora, West Philadelphia and moved there with his family in late summer, 1682.

Original text excerpt

Letter of 31 January 1683 from Thomas Paskell to a friend in Chippenham, England (Myers 1912, pp. 253, 254), describing the Pennsylvania colony, then limited to parts of present-day Philadelphia, lower Bucks and Delaware Counties:

> Here are Gardens with all sorts of Herbs, and some more then in England, also Goose-beries and Roasetrees, but what other Flowers I know not yet: Turnips, Parsnips, and cabbages, beyond Compare. Here are Peaches in abundance of three sorts I have seen rott on the Ground, and the Hogs eate them, they make good Spirits from them, also from Come and Cheries, and a sort of wild Plums and Grapes, and most people have Stills of Copper for that use. Here are Apples, and Pears, of several sorts, Cheries both Black and Red, and Plums, and Quinces; in some places Peach Stones grow up to bear in three Years … The Land is generally good and yet there is some but ordinary and barren ground. Here are Swamps which the Sweads prize much, and many people will want: And one thing more I shall tell you, I know a man together with two or three more, that have happened upon a piece of Land of some Hundred Acres, that is all cleare, without Trees, Bushes, Stumps, that may be Plowed without let, the farther a man goes into the Country the more such Land they find. There is also good Land, full of Large and small Trees, and some good Land, but few Trees on it. …

Interpretation of text

The second-to-last sentence in Paskell's letter is most likely the earliest unambiguous reference to grasslands or meadows in Pennsylvania.

"Open places," 1684

Background

William Penn (1644–1718), founder and proprietor of the province of Pennsylvania, first set foot in his North American landholdings in October 1682. This was nearly 40 years after the first European settlement in what is now Pennsylvania by Swedes and Finns and 18 years after the English had replaced the Dutch as military claimants of the European settlements along the Mid-Atlantic coast, including the area that was to become Penn's province. Despite several decades of prior European settlement, however, Native Americans still outnumbered the sparse European population. Penn's arrival inaugurated a dramatic increase in immigration rates.

Original text excerpt

Letter 9 January 1684 from William Penn to the Earl of Arran (Dunn and Dunn 1982, p. 513), describing the Pennsylvania colony, then limited to parts of present-day Philadelphia, lower Bucks and Delaware Counties:

> The land is generally good, well water'd & not So thick of wood as immagin'd; there are also many open places that have been old indian feilds.

Interpretation of text

This sentence corroborates Thomas Paskell's mention (see previous item) of scattered grasslands, meadows and savannas in and around Philadelphia County, which in all likelihood predated European settlement.

Vacant Indian fields at East Falls, Philadelphia, 1684

Background

The historian Paul A. W. Wallace, in researching the late prehistoric-early colonial Allegheny Path from present-day Philadelphia to Pittsburgh, found reference to what may have been its eastern terminus in a 1684 survey.

Original text excerpt

The words of an anonymous surveyor labeling a property survey map (Wallace 1965, p. 19):

> ... in a survey dated “13 of May 1684” ... “Mapp of Swan Swanson and his two Brothers land near [east of] ye ffalls of Skeolkill on ye S E side thereof ...” It shows, as approaching the river through “Vacant Indian Feilds,” “One Inden Road to Netopcomb or ye ffalls of Shoolkill.”

Interpretation of text

The “Vacant Indian Feilds” were apparently just east of where U.S. Route 1 (Roosevelt Expressway) crosses the Schuylkill River.

Grassy oak woodlands, 1685

Background

Thomas Budd, about whom little is known, wrote what is basically a real estate promotional brochure in 1685 and had it published by Philadelphia’s first printer for distribution in England.

Original text excerpt

Describing and perhaps exaggerating the positive attributes of the real estate in Penn’s province (Budd 1685, p. 34):

> The *Trees* grow but thin in most places, and very little under-Wood. In the *Woods* groweth plentifully a course sort of *Grass*, which is so proving that it soon makes the Cattel and Horses fat in the Summer, but the *Hay* being course, which is chiefly gotten on the fresh Marshes, the Cattel loseth their Flesh in the Winter and become very poor, except we give them Corn: But this may be remydied in time, by draining of low rich Land, and by plowing of it, and sowing it with *English*-Grass-seed, which here thrives very well. The *Hogs* are fat in the Woods when it is a good Mast-Year.

Interpretation of text

Budd’s is the earliest mention of vegetation in or near Philadelphia with an abundant growth of one or more native grass species. If accurate, the description could be interpreted as a grassy savanna, perhaps similar in appearance to the longleaf pine–wiregrass savannas of the southern Atlantic and Gulf of Mexico coastal plains or the oak savannas of the Midwest.

Vast treeless area in the Piedmont uplands of York County, 1722–1771

Background

The Maryland historian William Bose Marye (1886–1979) combed early records to reconstruct a large expanse of essentially treeless land at the time of first European settlement northwest of Baltimore, extending into York County, Pennsylvania, which he called the “Great Maryland Barrens.” A very small fraction of this land was underlain by serpentinite—the sole remnant today may be the serpentine grasslands at Soldiers Delight and Bare Hills near Baltimore—but most of it occupied ordinary soils and soon succeeded back to forest or was converted to agricultural use. In all likelihood, these lands were cleared of trees and the herbaceous and dwarf shrub cover sustained by Indian burning. The burning most likely came to a halt decades before Europeans arrived on the scene when waves of smallpox and other European diseases spreading inland from coastal points of contact, moving faster than the spread of settlers, decimated Native American populations, leading to disruption or collapse of their political systems, economies and land-use practices (Denevan 1992; Flannery 2001; Stewart 2002; Mann 2005).

Original text excerpts

Quoting Philemon Lloyd, Maryland provincial council member, in a letter addressed to unidentified “Co-Partners” dated 8 October 1722 (Marye 1955, p. 16):

> ... a Vast Body of Barrens; tht is, what is called so, because there is no wood upon it; besides Vast Quantities of Rockey Barrens. If this place would be seated [settled], it would be a good Barrier unto the Province [Maryland] on tht side, & doubt not, but it would in a few years, bring on the Planting of tht other Body of Rich Lands, tht Lyes something more to the Westward ...” [cited source: pp. 57-58 in 1894, Calvert Papers No. 1080, The Calvert Papers, Maryland Historical Society, Baltimore]

Quoting Charles Carroll, an Annapolis land speculator, in a letter to his son Charles Carroll dated ca. 1753 (Marye 1955, p. 17):

> ... about thirty miles from Navigable Water is a Range of barren dry Land without Timber about nine miles wide which keeps a Course about North East and South West parallel with the mountains thro this province Virginia & Pennsilvania but between that and the Mountains the lands mend and are Very good in Several parts. [cited source: p. 64 in 1930, Extracts from account and letter books of Dr. Charles Carroll of Annapolis, *Maryland Historical Magazine* **25**: 53-76]

Quoting a 1770 survey within the Maryland portion of the large treeless area that included the York Barrens (Marye 1955, pp. 20, 21):

> … about 50 acres of marsh & Glady Ground, about 200 acres of sapling Land 300 acres of Bare Barrens the Rest small Bushes. Soil of Both Bushy and barren Land is very thin and both Hilley, and Stoney, the soil of the Sapling Land is Middling ...

Quoting a 1771 certificate of survey of a 662-acre tract 4.5 miles south of the present-day Pennsylvania-Maryland border including part of the York Barrens (Marye 1955, p. 23):

> I do hereby certify that I have been thro the within mentioned survey Two different times and Took notice that their was a Pretty Large Marsh or Glade that might be made into meddow, the up land (all I saw) was Barrense, hilly and stony, except a very few acres. [signed] Jno. Merryman, Jun. I Do hereby Certify That I have Been throw the within Mentioned survey & Took Notice off the Quality of the Land, there is some Good Medow Ground for to make But the up Land is Poore hilly Barrance & much broke with stone & Verey scarce of Timber. [signed] JaSterett. I do hereby Certifie that I have been throw the best part of the within Mentioned survey and observed the Quality of the Land. There is about forty or fifty acres of glade commonly called medow ground, one third of which may be made into Tollerable good medow attended with great expense, being very flat and very difficult to take of the water. The up Land is exceedingly poor & much broke with stone and Little or no Timber of any sort. [signed] Benjamin Rogers. [cited source: Land Office, Annapolis, Patented Certificate No. 962, Baltimore County]

Part of Marye’s summary description of the York Barrens (Marye 1955, p. 120):

> … the Barrens extended along the west bank of Susquehanna River, in York County, from the mouth of Fishing Creek, opposite Turkey Hill, or thereabouts, to the Mason and Dixon line, a distance of nearly 21 miles, and backwards into the interior of the country, to include the valleys of Fishing Creek and Muddy Creek. The whole of the townships of Chanceford, Lower Chanceford, Peach Bottom, the southern part of Windsor, and all of Fawn and Hopewell Townships were included in the Barrens. But the Barrens did not extend much, if at all, to the westwards of the head stream of Deer Creek, which forms the boundary between Hopewell and Shrewsbury Townships. The Pennsylvania or York Barrens contained about 130,000 acres. According to Rupp [1845], this enormous extent of land was not called (ca. 1737-1735 [sic]) “the barrens” simply on account of the poverty of the soil, but because its early settlers found “no timber” upon it. In this important respect Rupp agrees with the statements of Lloyd and Carroll, of which he (most probably) had no knowledge.

Interpretation of text

By far the largest pre-settlement treeless area recorded in the greater Piedmont—in fact, within all of the present area of Pennsylvania—was the York Barrens, also known as the Slate Hills or Pigeon Hills, in southeastern York County (Carter and Glossbrenner 1834; Rupp 1845; Cooper 1903; Marye 1955). Marye estimated the York Barrens to have covered about 530 km^2 (130,000 acres). The two earliest mentions of the York Barrens described its size in terms of townships, each asserting that they covered all of four townships and part of another. Taking a conservative tack and assuming that an average of three-quarters of the "all" townships and one-quarter of the "part" township were treeless, the resulting estimates are 380 and 440 km^2 (93,100 and 108,200 acres) (Carter and Glossbrenner 1834; Rupp 1845). Applying the three-quarters/one-quarter formula to the townships listed in Marye's synopsis results in an estimate of 514 km^2 (127,000 acres), remarkably close to the author's conclusion. No information on the plant species composition of the York Barrens has been found.

Limestone prairies or savannas in the Cumberland and Conococheague Valleys, 1740–1887

Background

There are numerous second-hand descriptions of grasslands in the Cumberland Valley and Conococheague Valley at the time of European settlement, in the early to mid-eighteenth century, some of which were reported to have persisted into the early nineteenth century.

Original text excerpts

Quoting an historical address given in 1854 by a clergyman, in which he described grasslands in the mid-eighteenth century at Grindstone Hill, Franklin County (Orr 1904, pp. 25, 26):

> Six miles from Chambersburg, in a southeasterly direction, was a large section without timber, extending over parts of Gu[i]lford, Antrim and Quincy townships. ... On December 25, 1854, Rev. D. K. Focht delivered an historical address in Grindstone Hill church ... From a printed copy of Mr. Focht's address I quote, "when the first settlers came here, the church lands, like most of the lands, were almost entirely destitute of timber. Here and there might be seen a cluster of young saplings in the low ground, between the church and Grindstone hill. As the fire was kept off the lands, the sprouts from old stumps grew up in great profusion and at the time the old church was erected (in about 1766), they had grown to the height of a man, and the settlers could still run over them with a wagon."

Describing grasslands in the mid-eighteenth century east of Middlespring, Cumberland County (Orr 1904, pp. 22-23):

> The country around Middlespring proper is limestone and hilly. Passing eastward a short distance we reach a large plain similar to many other sections of the valley. At its settlement it was without timber excepting here and there a few large trees. Its extent eastward was three to four miles and probably of greater length and varying in width; narrow at its beginning and at some places widening to two or three miles. Like the other treeless lands of the valley known as barrens, young sprouts began to grow when they were protected and in due course of time these grew into thickets of underbrush and small trees from which come the forests of later generations.
>
> In 1740 [John Reynolds] was granted a warrant by the province of Pennsylvania for 433 acres in one tract, and a meadow of 36 acres in another. The large tract began at a hickory tree on the west side of Midway Spring, running eastward to the barrens, as it is marked on the draft in the Internal Department, at Harrisburg. Beyond these "barrens" lay his meadows of 36 acres, which adjoined the pine lands running to the South mountain. This tract of "barrens" was not included in his grant and where it touched and separated his lands had an area of about 100 acres. It ran north eastward from the pine lands toward the "barrens" near Middlespring, and doubtless was a portion of the same tract.

Describing grasslands in the mid-eighteenth century near Shippensburg, Cumberland and Franklin Counties (Orr 1904, pp. 24, 25):

> Going southward from Shippensburg a mile or more we find another large section of limestone land similar in its early conditions to the lands to which I have referred. It reached from the "pine lands" along the foot of the South mountain, to a section of limestone, part of which formed Culbertson's Row, and extending southward towards and beyond Greenvillage; embracing over fifteen hundred acres. This "barrens" is hilly, the rocks lied near the surface and it is almost devoid of running streams, making it one of the dry sections of the valley. ... This treeless tract ran in part through lands of Joseph Culbertson, Michael Kerr or Carr, James Breckenridge, Robert Mahon and others, who settled there before 1740. For verification of these statements I have them of my personal knowledge in that vicinity from those who

> were born before 1800 and lived until after 1860, and saw and were familiar with this section when the timber was young, and they had from their parents its condition as early as 1740.

Describing grasslands in the early nineteenth century near Quincy, Franklin County (Orr 1904, p. 27):

> ... I had a conversation with Samuel Helman, who spent the 80 years of his life on the same farm ... His story of the "barrens," etc., was partly of his own early observation. He was born in 1820, and in his boyhood the timber growing on these "barrens" was small and little of it was used for building purposes. ... his father built a barn and two or three log houses of pine logs, brought from the pine lands, because the timber on his own lands was much too small for building purposes. This was after 1800, and as late as 1825 to 1830, most of the timber was small. ... In some portions of this large area the natural grasses grew to a height of three feet and two crops were cut in one season.

Describing grasslands in the mid-eighteenth century at Campbells Run, Franklin County (Orr 1904, p. 28):

> Stretching westward from Campbell's run in St. Thomas township there lies a large area of land that was known as the "barrens" in the early settlement of that part of the valley. It was without timber and in many places well covered with natural grasses. Extending from the foot of the North or Kittochtinny mountains down into the valley until these "barrens" were reached the land was covered with a heavy growth of timber. The difference in the size of the timber is easily discernible between this and that which later grew on the "barrens" where it is yet standing. These "barrens" began a short distance west of Campbell's run and extended westward over the limestone lands, south of Fort Loudon, up towards Mercersburg. As late and later than 1790 the growth of the timber on these lands had not reached a heighth [sic] beyond three to five feet and much of it was covered with a heavy undergrowth.

Describing wet meadows in the mid-eighteenth to early nineteenth century known as "The Marsh," Franklin County (Orr 1904, p. 28):

> ... at the time of settlement it embraced several hundred acres. It was level, swampy land, covered with grass, with trees on its outer edges. These swamps were drained and turned into productive farms. As late as 1820 there were over 100 acres of this marsh land in its original condition.

Quoting a clergyman, Michael Schlatter (1716–1790), writing of a visit in 1748 to the Conococheague Valley, Franklin County (Harbaugh 1857, pp. 171, 172):

> ... we did not arrive in Connogocheague till two o'clock in the morning of the 9th [of May], when we came to the house of an honest Swiss, and gratefully enjoyed a very pleasant rest. ... Here in this region there are very fruitful fields for grain and pasture; they produce Turkish corn almost without any manure, among which are stalks ten and more feet long; and the grass is exceedingly fine. In this neighborhood there are still many Indians ...

Describing grasslands in the mid-eighteenth century in the Conococheague Valley, Franklin County (M'Cauley 1878, p. 10):

> It is a tradition, well supported, that a great part of the best lands in the Conococheague Valley were, at the first settlement of the country, what is now called in the Western states prairie. The land was without timber, covered with a rich, luxuriant grass, with some scattered trees, hazel bushes, wild plums and crab apples. It was then generally called "the barrens." The timber was to be found on or near the water courses, and on the slate [shale] soil. This accounts for the preference given by the early Scotch-Irish settlers to the slate lands before the limestone lands were surveyed or located. The slate lands had the attractions of wood, water courses and water meadows, and were free from rock at the surface. Before the introduction of clover, artificial [cultivated] grasses, and the improved system of agriculture, the hilly limestone land had its soil washed off, was disfigured with great gullies, and was sold as unprofitable, for a trifle, by the proprietors, who sought other lands in Western Pennsylvania.

Describing "barrens" in the mid-eighteenth century in the Cumberland Valley around Mechanicsburg (Cumberland County (Rupp 1846, quoted in Orr 1904, p. 20):

> His father, an aged man, informed him that when he was a lad he saw from his father's house wolves pursuing a deer a mile or more in the direction of Mechanicsburg. It should be borne in mind that the region of country between the Conodoguinett [sic] and Yellow Breeches, from the Susquehanna, to ten or

> twelve miles westward, was a barrens; not a tree to be seen on a thousand acres.

Describing "barrens" in the mid-eighteenth century in the Conococheague Valley, Franklin County (Harbaugh 1857, p. 172):

> Here the first settlement of the county was made, the first settlers being Germans ... The settled on the Connogocheague, because in it they found good timber for building and other uses, whilst the rest of the valley was destitute of timber, and only covered with scrub-oak and hazle-bushes.

Describing grasslands in the mid-eighteenth century in the Conococheague Valley, Franklin County (Bates and Richard 1887, quoted in Losensky 1961, p. 25):

> A rich luxuriance of grass is said to have covered the whole valley, wild fruits abounded, and in some parts the trees were of singular variety.

Interpretation of text

None of these accounts gives any clues about the herbaceous species present there except for one, which noted "the natural grasses grew to a height of three feet and two crops were cut in one season."

Limestone prairie in the Lehigh Valley near Easton, 1743–1765

Background

Several documents from the mid-eighteenth century mentioned a large area west and northwest of Easton called the "Barrens" or "Dry Lands."

Original text excerpts

Count Nikolas Ludwig von Zinzendorf (1700–1760), a German count and missionary who visited Pennsylvania in the 1740s, in a letter dated 15 March 1743 to Augustus Gottlieb Spangenberg (1704–1792), a German bishop in the Moravian Church serving at a mission in Bethlehem, Pennsylvania, at the time (quoted in Henry 1860, p. 78):

> It would be no more than right for the proprietaries to make us a present of the ground over which it [the road between Bethlehem and Nazareth] passes, because usually all the roads are given gratis, and because the width of this one is of no account to the proprietaries, the country through which it passes being absolutely a desert without wood or water, and of such a nature that it *never can be sold*. … the rate of £15 per hundred, is an excessive price, inasmuch as those parts of the forks called the Dry Lands *are worth nothing* at all, and nobody wants them.

William Parsons (1701–1757), a Philadelphia shoemaker who became the surveyor general of the Pennsylvania province, in a letter dated 3 December 1752 to Richard Peters (1704–1776), secretary of the Pennsylvania land office, describing the town of Easton and its surroundings (quoted in Henry 1860, pp. 53, 54):

> … it must be confessed that the town labors under several considerable disadvantages. The first that offers, I mention with submission, is the great tract of land called the Dry Land, to the westward of the town. This, with another tract adjoining the town to the northward, being altogether about 20,000 acres, is almost the only part of the country that, by its nearness to the town, were it settled and improved, could conveniently and readily afford a constant supply of provisions of all kinds ... For as long as it remains uncultivated, it will serve for range to the town cattle."

A petition presented to the provincial assembly of Pennsylvania on 15 May 1765 to move the county seat of the newly formed Northampton County from Easton to a more convenient location (quoted in Henry 1860, p. 77):

> … that, in particular the road to Easton is extremely inconvenient, passing through a large tract of land called the Dry Lands, so thinly inhabited that, in the distance of twelve miles from Bethlehem to Easton, there is but one or two huts, and not one drop of water, neither in the summer or fall seasons, to refresh either man or horse, so that in winter travelers are in danger of perishing with cold, or of being parched up in summer with heat ...

Interpretation of text

The area mentioned was fertile farmland by the mid-nineteenth century (Henry 1860), so its barren appearance a century earlier must have been due to repeated burning before any Europeans who might have recorded such a practice arrived on the scene. The only clues to the appearance of the vegetation in these texts is Count von Zinzendorf's description of it as "a desert without wood" and William Parsons' mention that it was used only as a free range for cattle, which together suggest a grassland.

Earliest mention of serpentine grasslands, 1745

Background

Philadelphia botanist John Bartram (1699–1777), the first botanist of European descent born in the Americas, made the earliest written mention of serpentine grasslands in Pennsylvania uncovered so far.

Original text excerpt

John Bartram in a letter dated 6 December 1745, to the Dutch naturalist John Frederic Gronovius (Berkeley and Berkeley 1992, pp. 265, 266):

> Ye Loadstone [magnetite] lieth in a vein of a particular kind of stone that runs near east and west for sixty or seventy miles or more, appearing even with, or a little higher than its surface, at three, five, eight, or ten miles distance, and from ten to twenty yards broad, generally mixed with some veins of cotton [asbestos]. Ye earth of each side is very black, and produceth a very odd, pretty kind of Lychnis [moss phlox], with leaves as narrow and short as our Red Cedar, of humble growth, perennial, and so early as to flower, sometimes, while the snow is on the ground; also a very pretty Alsine [barrens chickweed]. Hardly anything else grows here. Our people call them Barrens ...

Interpretation of text

The prominence of moss phlox (*Phlox subulata* var. *subulata*) in Bartram's description suggests that he may have been referring to one or more sites in present-day Delaware County or eastern Chester County that were later well known among botanists and local gardeners for the abundance of this species (Harshberger 1903).

Grasslands, heaths and open woodlands around Philadelphia, 1748–1749

Background

Pehr Kalm (1716–1779) was a Swedish-Finnish explorer, botanist, naturalist, agricultural economist and student of Carl von Linné (Carolus Linnaeus), who engaged him in 1747 on behalf of the Royal Swedish Academy of Sciences to make botanical observations in North America. Kalm arrived in Pennsylvania in 1748, befriended Benjamin Franklin and John Bartram (North America's first native-born botanist of European descent), and settled until 1751 at Raccoon, a Swedish-Finnish community just across the Delaware River from Philadelphia in New Jersey, now called Swedesboro. He spent most of his North American stay in and around Philadelphia but his diaries (Benson 1937) also describe his travels in other parts of Pennsylvania and New Jersey and to New York and Quebec.

His diaries mention over 300 species of plants (also many kinds of animals, fungi and minerals) by their Linnaean binomials, but mainly to describe their appearance, the ways in which they were used by people, or any adverse effects on people. However, some entries describe plants species' habitat relations and the types of vegetation he encountered. In most cases, the geographical locations of his descriptions are clear, but sometimes while describing a species in one location he generalized about its occurrence elsewhere. The excerpts included here are those that appear to refer with the least ambiguity to present-day Philadelphia County and neighboring portions of Bucks and Delaware Counties.

Note that for Kalm the place name *Philadelphia* referred, not to the present-day 13-county metropolitan area including parts of four states or the 135-square-mile county (boundary finalized in 1784) and city (consolidated with the county in 1854), but to a small town on the banks of the Delaware River. In the mid-18th century the town covered roughly 1 square mile, corresponding to the present neighborhoods of Old City, Society Hill and the east end of Center City. Thus, when he wrote "near Philadelphia" Kalm would have meant within a few miles of the town and well within the present limits of Philadelphia County.

Original text excerpts

Pehr Kalm's diary entry for 26 September 1748 (Benson 1937, p. 68), describing useful native or wild plants:

> The *Sarothra* [*Hypericum*] *gentianoides* grows abundantly in the fields and under the bushes in a dry sandy ground near Philadelphia. It looks much like our whortleberry bushes when they first begin to grow green and when the points of the leaves are still red. … It is reckoned a very good traumatic, and this quality Mr. Bartram himself experienced, for once being thrown and kicked by a vicious horse in such a manner as to have both his thighs greatly hurt, he boiled the *Sarothra* and applied it to his wounds. Thereupon it not only immediately appeased his pain, which before had been violent, but by its assistance he recovered in a short time.

Pehr Kalm's diary entry for 28 September 1748 (Benson 1937, pp. 70, 71), continuing his description of useful native plants:

> The *Gnaphalium margaritaceum* [*Anaphalis margaritacea*] grows in astonishing quantities upon all uncultivated fields, glades, hills and the like. Its height varies with the soil and location. Sometimes it is very ramose and sometimes very small. It has a strong but agreeable smell. The English call it "life everlasting," for its flowers, which consist chiefly of dry, shining, silvery leaves (*Folia calycina*) do not change when dried. … The English ladies are accustomed to gather great quantities of this life everlasting and to pick them with the stalks. For they put them into pots … and place them as an ornament in the rooms. … Mr. Bartram told me another use of this plant: a decoction of the flowers and stalks is used to bathe pained or bruised parts of the body, or they may be rubbed with the plant itself tied up in a thin cloth or bag.

Pehr Kalm's diary entry for 5 October 1748 (Benson 1937, p. 86), at Chichester, southwestern Delaware County:

> The *American brambles* (*Rubus occidentalis* L.) are here in great abundance. When a field is left uncultivated they are the first plants to appear on it, and I frequently observed them in such fields as are annually plowed and have grain sowed on them. For when these bushes are once rooted they are not easily extirpated. … On some old land which had long been uncultivated there were so many bushes of this kind that it was very troublesome and dangerous walking among them. …

Pehr Kalm's diary entry for 27 October 1748 (Benson 1937, pp. 116, 117), describing a journey from Philadelphia to Bristol, on the Delaware River in Bucks County:

> We now saw country estates on both sides of the road. We came into a lane bordered with pales [sic] on both sides and enclosing rather large cultivated fields. Next followed a wood, and we perceived for the space of four English miles nothing else, except a very poor soil on which the *Lupinus perennis* grew plentifully and succeeded well. I was overjoyed to see a plant thrive so well in these poor dry places, since it served to make such places useful. But I afterwards had the mortification to find that the horses and cows eat almost all other plants, save the lupine, which was however very green, looked very luxuriant, and was extremely soft to the touch. Perhaps means may be found of making this plant palatable to cattle.

Pehr Kalm's diary entry for 22 November 1748 (Benson 1937, pp. 180, 181), describing native grasses:

> *Grass.* Åke Helm was one of the most important Swedes in this place and his father came over to this country along with the Swedish Governor Printz; he was upwards of seventy years of age. This old man told us, that in his youth there was grass in the woods which grew very thick, and was everywhere two feet high, but that it was so much thinner at present that the cattle could hardly find food enough, and that therefore four cows now gave no more milk than one at that time. The causes for this change are easy to find. In the younger days of old Helm the country was little inhabited, and hardly a tenth part of the cattle kept which is there at present. A cow had therefore as much food at that time as ten now have. Further, most grasses here are annuals, and do not for several years in succession shoot up from the same root as our Swedish grasses. They must sow themselves every year, because the last year's plant dies away every autumn. The great numbers of cattle hinder this sowing, as the grass is eaten before it can produce flowers and seed. We need not therefore wonder that the grass is so thin on fields, hills and pastures in these provinces. This is likewise the reason why travellers in New Jersey, Pennsylvania and Maryland find many difficulties, especially in winter, to travel with their horses, for the grass in these provinces is

not very abundant, the cattle having eaten it before it goes to seed. …

Pehr Kalm's diary entry for 27 March 1749 (Benson 1937, p. 269), describing Indian corn cultivation (note: *Andropogon bicornis* L. is a tropical American species, which superficially most resembles, in the southeastern Pennsylvania native flora, *A. glomeratus*, but is typically much taller [Clayton et al. 2008]; Kalm may have been referring to *A. gerardii*, *Sorghastrum nutans* or other local members of the tribe Andropogoneae):

… After they had reaped the corn, they kept it in holes under ground during winter; they seldom dug these holes deeper than a fathom, and often not so deep; at the bottom and on the sides they put broad pieces of bark. If bark could not be had, the *Andropogon bicorne*, a grass which grows in great plenty here, and which the English call Indian grass and the Swedes wildgrass, supplied the want of the former. …

Pehr Kalm's diary entry for 12 April 1749 (Benson 1937, pp. 279, 280), describing grass management by burning (and expressing his disapproval of the practice):

Reckless Burning. The leaves which dropped last autumn had covered the ground three or four inches in depth. As this seemed to hinder the growth of the grass, it was customary to burn it in March, or at the end of that month (according to the old style), in order to give the grass the opportunity of growing up. I found several spots burnt in this manner to-day; but if it be useful one way, it does a great deal of damage in another. All the young shoots of several trees were burnt with the dead leaves, which diminishes the wood and timber considerably; and in places where the dead leaves had been burnt for several years in succession the old trees only were left, which being cut down, there remained nothing but a large field, and without any wood. At the same time all sorts of trees and plants were consumed by the fire, or at least deprived of their power of budding. Now, a great number of the plants and most of the grasses here are annuals; their seeds fall between the leaves, and by that means are burnt. This is another cause of universal complaint that grass is much scarcer at present in the woods than it was formerly. A great number of dry and hollow trees are burnt at the same time, though they could serve as fuel in the houses, and by that means spare part of the forests. The upper mould likewise burns away in part by that means, not to mention several other inconveniences with which this burning of the dead leaves is attended. To this purpose the government of Pennsylvania has lately published an edict which prohibits this burning; but everyone does as he pleases and this prohibition meets with a general censure.

Pehr Kalm's diary entry for 26 April 1749 (Benson 1937, pp. 288, 289), describing the impact of cattle grazing on forest understories:

The Lupine. The *Lupinus perennis* is abundant in the woods, and grows equally well in good soil and in poor. I often found it thriving on very poor sandy fields, and on heaths, where no other plants will grow. Its flowers, which commonly appear in the middle of May, make a fine show by their purple hue. I was told, that the cattle eat these flowers very greedily; but I was sorry to find very often that they were not so fond of it, as it is represented, especially when they had anything else to eat; and they seldom touched it notwithstanding its fine green color and its softness. The horses eat the flowers, but leave the stalks and leaves. 1f ever the cattle eat this plant in spring it is because of necessity and hunger, which give it a relish. This country does not afford any green pastures like the Swedish ones; the woods are the places where the cattle must collect their food. The ground in the woods is quite even with gently rising knolls. The trees stand far apart, but the ground between them is not covered with greensod, for there are but few kinds of grass in the woods, and the blades of it stand single and scattered. The soil is very loose, partly owing to the dead leaves which cover the ground during a great part of the year. Thus the cattle find very little grass in the forests and are forced to be satisfied with all kinds of plants which come in their way, whether they be good or bad food. I saw all spring long how the cattle bit off the tops and shoots of young trees and ate them; for no plants had come up and they stood in general but very thin, scattered here and there, as I have just mentioned. Hence you may easily imagine that hunger compels the cattle to eat plants which they would not touch, were they better provided for. However, I am of the opinion that it would be worth while to make use of this lupine to improve dry sandy heaths, and, I believe, it would not be absolutely impossible to find out the means of making it agreeable to the cattle.

Pehr Kalm's diary entry for 1 May 1749 (Benson 1937, p. 291), describing Indian paintbrush:

> The *Bartsia* [*Castilleja*] *coccinea* grew in great abundance on several low meadows. Its flower buds were already tinged with a beautiful scarlet which adorned the meadows. …

Interpretation of text

Kalm focused on grasses in his descriptions of mid-eighteenth-century southeastern Pennsylvania in only three passages (although he named several species in recounting his travels in New York and Quebec). He interviewed an old man who recalled, in the late 1600s, "grass in the woods which grew very thick, and was everywhere two feet high" but had become "much thinner at present." Kalm attributed its decline to overgrazing by cattle, theorizing "most grasses here are annuals, and do not for several years in succession shoot up from the same root as our Swedish grasses. They must sow themselves every year, because the last year's plant dies away every autumn. The great numbers of cattle hinder this sowing, as the grass is eaten before it can produce flowers and seed." Kalm mentioned only one native grass in Pennsylvania by species: "*Andropogon bicorne*, a grass which grows in great plenty here, and which the English call Indian grass and the Swedes wildgrass." Unfortunately this is a misidentification; *Andropogon bicornis* L. is a tropical American species, which superficially most resembles, in the southeastern Pennsylvania native flora, *A. glomeratus*, but is typically much taller (Clayton et al. 2008). Kalm may have been referring to *A. gerardii*, *Sorghastrum nutans*, or other local members of the tribe Andropogoneae. In another passage he described grass management by burning: "The leaves which dropped last autumn had covered the ground three or four inches in depth. As this seemed to hinder the growth of the grass, it was customary to burn it in March, or at the end of that month (according to the old style), in order to give the grass the opportunity of growing up. I found several spots burnt in this manner to-day [12 April 1749]." At some length following these sentences Kalm made clear his disapproval of the practice.

Species in grasslands and meadows that Kalm reported as abundant but that are now rare or absent in the area include lupine ("… we perceived for the space of four English miles nothing else, except a very poor soil on which the *Lupinus perennis* grew plentifully …"), Indian paintbrush ("… *Bartsia* [*Castilleja*] *coccinea* grew in great abundance on several low meadows"), sheep-laurel ("*Kalmia angustifolia* was now everywhere in flower. It grows chiefly on sandy heaths, or on dry poor grounds, where few other plants thrive; it is common in Pennsylvania …"), orange-grass ("… *Sarothra* [*Hypericum*] *gentianoides* grows abundantly in the fields and under the bushes in a dry sandy ground …") and pearly-everlasting ("… *Gnaphalium margaritaceum* [*Anaphalis margaritacea*] grows in astonishing quantities upon all uncultivated fields, glades, hills and the like"). Trees, woody vines and shrubs mentioned as characterizing old fields, pastures, fencerows and corn fields were smooth sumac, American chestnut, black walnut, greenbrier, red mulberry and hackberry.

Indian burning on the southern Pocono Plateau, 1758

Background

Isaac Zane, in late June 1758, was engaged by a Quaker philanthropic association in Bucks County to muster a small group to the Wyoming Valley (present-day Wilkes Barre and vicinity) to join a work crew commissioned by the colonial government in building a town for a group of Lenapes displaced by European settlers (Coates 1906).

Original text excerpt

Diary entry by Isaac Zane, dated 26 "5th mo." (July) 1758 (Coates 1906, p. 420):

> We after a good nights Rest arose Early getherd our thing to gether went forward over great hills & Dales & large streems of water & vew[d] the theikis of real pine Swamps … But most of ye land is a poor Sovana which the Indians burn once in 3 or 4 years and kills such scrub wood as grow on it. Except in som very stony or very wet land and for many miles going I did not see a hand full of grass growing but there is sundry sorts of plants of Evergreens, somthing like ground Ive.

Interpretation of text

Such a record, noting a detail of Native American burning practices in eastern North America, is rare indeed. He clearly and succinctly described a dwarf shrub savanna dominated by low-growing members of the Ericaceae or heath family. Based on Zane's daily descriptions of the landscape, including place names in the settled areas, his route can be estimated with some confidence; the "Sovana" he described is almost certainly the Pocono till barrens, where dwarf shrub savanna dominated by heaths is still present today, although probably much reduced in area from its extent in 1758 (Latham 2003).

"Great Plains" in the Ridge and Valley, 1775

Background

Philip Vickers Fithian (1747–1776) was a clergyman and missionary renowned after his lifetime as a vivid diarist of life in colonial Virginia and the Susquehanna Valley of Pennsylvania and as a strong critic of slavery. For the two years prior to his death before the age of 30, he was sent on a backcountry missionary tour, which is when he briefly described the "Great Plains" of Penns Valley, Centre County, Pennsylvania, and the "Glades" of Kishacoquillas Valley, Mifflin and Huntingdon Counties, Pennsylvania.

Original text excerpts

Diary entries by Philip Vickers Fithian dated August 1775 (Fithian 1775-1776, reprinted in Albion and Dodson 1934; quoted in Losensky 1961, pp. 26, 40, 41):

> The land [in Kishacoquillas Valley] is almost all usable, and will support two large societies. There are indeed large plains or, as the inhabitants call them, "Glades," quite bare of timber and covered with shrubs, Ground Oak, Hazels, etc. Some, too, is broken with limestone and some is wholly barren covered with pines.
>
> In the valley [Penns Valley] there are large open plains, cleared either by Indians or accidental fire. Hundreds of acres are covered with fine grass, mixed with small weeds and a great variety of flowers. Some conjecture that hot blasting fumes which arise from acres of brimstone have destroyed the timber, and they have found in places fine unmixed brimstone that will burn quite away without leaving any dross.

Interpretation of text

Fithian's was somewhat more detailed than any earlier descriptions of grasslands on limestone soils in Pennsylvania. His mention of fume-emitting "brimstone" as a possible cause of a grassland in an overwhelmingly forested region reflects an assumption common throughout most of the first 400 years of European settlement in eastern North America, that the indigenous Indians were incapable of engineering significant or persistent change in the landscape.

Aftermath of Indian burning near Lancaster, 1801

Background

John Pearson (1740–1829) served for many years as a justice of the peace, was elected to a term in the state senate, and was co-founder and secretary of "the Friendly Society for diffusing usefull knowledge," in Darby, then in Chester County. His powers of observation and intellectual curiosity were evident in extensive written observations, which he called his "gleanings."

Original text excerpt

Notes by John Pearson written in early 1801 on the occasion of his moving to Lancaster (the state's capital 1799–1812) to take his seat in the senate (Pearson 1801, reprinted in Mast 1957, pp. 55, 56):

> Columbia is distant about ten miles from Lancaster; the country between them near the road is highly valuable and said to be worth about twenty-five pounds p. acre ... The woods for the most part small the trees appearing to be from five to forty or fifty years old; black, spanish and white oaks but principally black oaks interspersed with some few walnut locust and ash. I had almost forgot to mention the hickory of which there is a considerable quantity and many of them old; among the smallest timber you see some of all kinds who appear to have survived the frequent conflagrations of

former times when it was the practice of the Indians to burn the woods annually.

Interpretation of text

The areas described by Pearson seem to have been on their way to growing back into forest after the cessation of regular burning, similar to other areas not far away described in the documents compiled by Marye (see under *Vast treeless area in the Piedmont uplands of York County, 1722–1771*, above). These areas were not part of the territory occupied by the Lenape around the time of European contact, but rather of the Susquehannocks, an Iroquoian-speaking nation of town-dwellers, culturally very different from the Lenape, who spoke an unrelated Algonkian language and lived in seasonal camps and hamlets.

First-ever site-specific comprehensive species list, including a riverine grassland or meadow in Bucks County, 1884–1887

Background

Over four years beginning in 1884, amateur botanist brothers John (1859–1918) and Harvey (1866–1904) Ruth conducted a vascular plant species inventory of Wykers Island, now known as Lynn Island, in the Delaware River, Bucks County, Pennsylvania, which was partly forested and partly covered by grassland or meadow. Theirs is one of the earliest known detailed descriptions of native plant communities in the region. It is a unique "snapshot" of the species composition of a riverine floodplain from a time before most of the native plant communities on riverine floodplains in the region were greatly altered by invasive plants and plant pathogens introduced from Eurasia.

Original text excerpts

Notes by John Ruth written in 1884–1887 describing the flora of Wykers Island (Ruth 1881–1917; excerpted in Latham and Rhoads 2006, pp. 31-38). Only selected species from the grassland and meadow flora of the island are included in the material presented here (updated nomenclature or corrected spellings are added in brackets):

> Jan. 20 – 1884. … The island is not a large one, but is covered with a dense mass of vegetation, and doubtless some very interesting plants. … The northern end is covered with cobble stones, and overgrown with low bushes and grasses.
>
> Aug. 23 – 1884…. We found the grasses fine and abundant. The Leguminosae were well represented by the Lupine and by a number of species of Desmodium and Lespedeza.
>
> July 29th. 1885. …
> 7. Cassia chamaecrista, L. Partridge Pea. [*Chamaecrista fasciculata* (Michx.) Greene] …
> 8. Helianthus giganteus, L. Giant Sunflower.
> 9. Hypericum pyramidatum, Ait. Great St. John's-wort.
> 10. Cenchrus tribuloides, L. Sand Bur. Bur Grass.
> 11. Panicum capillare, L. Old-witch Grass.
> 15. Chrysopogon nutans, Benth. Indian Grass. [*Sorghastrum n.* (L.) Nash]
> 18. Lysimachia quadrifolia, L. Four-leaved Loosestrife.
> 19. Verbena urticifolia, L. White Vervain.
> 20. Verbena hastata, L. Blue Vervain.
> 21. Tradescantia Virginica, L. Common Spiderwort. [*virginiana*]
> 22. Scutellaria laterifolia, L. Mad-dog Skullcap. [*lateriflora*]
> 33. Baptisia tinctoria, R.Br. Wild Indigo. [(L.) Vent.]
> 35. Aster patens, Ait. Spreading Aster. [*Symphyotrichum p.* (Ait.) Nesom]
> 36. Asclepias tuberosa, L. Pleurisy Root.
> 38. Panicum clandestinum, L. Hidden-flowered Panic Grass.
> 39. Rudbeckia hirta, L. Cone Flower.
> 46. Panicum dichotomum, L. Polymorphus Panic Grass.
> 47. Cassia Marilandica, L. Wild Senna. [*Senna m.* (L.) Link]
> 48. Euphorbia corollata, L. Flowering Spurge.
> 50. Teucrium Canadense, L. Germander.
> 51. Rhyncospora glomerata, Vahl. Common Beak Rush. [*Rhynchospora capitellata* (Michx.) Vahl]
> 52. Eupatorium purpureum, L. Joe Pye Weed.
> 57. Potentilla Canadensis, L. Common Cinque-foil.
> 58. Lespedeza capitata, Mx. Capitate Bush Clover.
> 59. Tephrosia Virginiana, Pers. Goat's Rue. [(L.) Pers.]
> 64. Apocynum cannabinum, L. Indian Hemp.
> 66. Andropogon scoparius, Mx. Purple Wood Grass. [*Schizachyrium scoparium* (Michx.) Nash]
> 67. Cyperus inflexus, Muhl. Dwarf Galingale.

[*C. squarrosus* L.]
68. Eleocharis obtusa, Schultes. Obtuse Spike-rush. [(Willd.) Schultes]
70. Eupatorium perfoliatum, L. Thoroughwort.
71. Hypericum ellipticum, Hook. Elliptic St. John's-wort.
72. Hypericum mutilum, L. Dwarf St. John's-wort.
73. Lysimachia ciliata, L. Fringed Loosestrife.
74. Lysimachia stricta, Ait. Spiked Loosestrife. [*L. terrestris* (L.) BSP]
75. Andropogon furcatus, Muhl. Finger-spiked Wood Grass. [*A. gerardii* Vitman]
76. Equisetum arvense, L. Common Horsetail.
77. Equisetum hyemale, L. Scouring Rush. 1884.
78. Ambrosia artemisiaefolia, L. Ragweed. [*artemisiifolia*]
80. Cyperus phymatodes, Muhl. Straw Sedge. [*C. esculentus* L.]
81. Juncus acuminatus, Mx. Var. legitimus, Gr. Sharp-fruited Rush.
82. Juncus tenuis, Willd. Slender Rush.
83. Cyperus dentatus, Torr. Toothed Galingale.
84. Prunus pumila, L. Dwarf Cherry.
85. Desmodium Canadense, DC. Canada Tick Trefoil. [(L.) DC.]
86. Eragrostis pilosa, Beauv. Slender Meadow Grass. [(L.) Beauv.]
87. Solidago lanceolata, L. Lanceolate Golden-rod. [*Euthamia graminifolia* (L.) Nutt.]
90. Agrostis scabra, Willd. Hair Grass.
91. Cuscuta gronovii, Willd. Common Dodder.
92. Spartina cynosuroides, Willd. Fresh water Cord Grass. [*S. pectinata* Link]
93. Panicum virgatum, L. Tall, Smooth Panic Grass.
94. Panicum agrostoides, Spreng. Agrostis-like Panic Grass. [*P. rigidulum* Nees]
95. Panicum proliferum, Lam. Prolific Panic Grass. 1884. [*P. dichotomiflorum* Michx.]
97. Cirsium discolor, Spreng. Two colored Thistle. 1884. [(Muhl.) Spreng.]
98. Lupinus perennis, L. Wild Lupine. 1884.
… Grasses are plentiful. The above list contains 18 species.

August 21st. 1885. Made another trip to Wyker's Island yesterday for the purpose of collecting its flora. Found Cyperus dentatus and Sparatina cynosuroides [*Spartina pectinata*] well established. …
107. Cirsium altissimus Willd. Tallest Thistle. [*C. altissimum* (L.) Spreng.]
108. Poa serrotina, Ehrhart. Foul Meadow Grass. [*P. palustris* L.]
109. Tricuspis seslerioides, Torr. Tall Red Top. [*Tridens flavus* (L.) A.S.Hitchc.]
110. Bromus ciliatus, L. Var. purgans, Gr. Fringed Brome Grass.
115. Silene stellata, Ait. Starry Campion. [(L.) Ait.f.]
116. Anemone Virginiana, L. Virginian Anemone.
117. Elymus striatus, Willd. Slender Lyme Grass.
120. Epilobium coloratum, Muhl. Willow Herb. [Biehler]
123. Thalictrum cornuti, L. Tall Meadow Rue. [*T. pubescens* Pursh]
128. Erechthites hieracifolia, Raf. Fireweed. [*Erechtites hieraciifolia* (L.) Raf. ex DC.]
130. Euphorbia maculata, L. Spotted Spurge. [*Chamaesyce m.* (L.) Small]
131. Leersia oryzoides, Swartz. Rice Cut Grass. [(L.) Swartz]
132. Bidens frondosa, L. Common Beggar-ticks.
133. Oenothera biennis, L. Evening Primrose.
134. Ipomoea pandurata, Meyer. Wild Potato-vine. [(L.) G.F.W.Mey.]
135. Helenium autumnale, L. Sneeze-weed.
138. Gerardia tenuifolia, Vahl. Slender-leaved Gerardia. [*Agalinis t.* (Vahl) Raf.]
139. Cyperus strigosus, L. Bristly-spiked Galingale.
140. Aster ericoides, L. Heath-like Aster. [*Symphyotrichum e.* (L.) Nesom]
141. Leersia Virginica, Willd. White Grass.
142. Cyperus diandrus, Torr. Diandrus Sedge.
144. Ambrosia trifida, L. Great Ragweed.
145. Vernonia Noveboracensis, Willd. Iron-weed. [(L.) Michx.]
146. Xanthium Canadense, Mill. Common Cocklebur. [*X. strumarium* L. var. *canadense* (P.Mill.) Torr. & A.Gray]
147. Gaura biennis, L. Gaura.
148. Lactuca Canadensis, L. Wild Lettuce.
151. Cinna arundinacea, L. Wood Reed Grass.
152. Carex comosa, Boot.
153. Muhlenbergia Mexicana, Trin. Mexican Muhlenbergia. [(L.) Trin.]
154. Muhlenbergia sylvatica, Torr. & Gr. Sylvan Muhlenbergia. [(Torr.) Torr. ex A.Gray]
155. Carex stipata, Muhl. Awn-fruited Sedge.

May 20th. 1887. … Near by we found large beds of Lupine in flower. This is a splendid plant. I never saw such fine plants of it before. …
157. Thalictrum dioicum, L. Early Meadow Rue.
158. Saxifraga Virginiensis, Mx. Virginian Saxifrage.
166. Erigeron bellidifolium, Muhl. Robin's Plaintain. [*E. pulchellus* Michx.]

172. Phlox subulata, L. Moss Pink.
173. Cerastium arvense, L. Field Chickweed.

October 1st. 1887. … Aster patens, Ait. [*Symphyotrichum p.* (Ait.) Nesom] is very abundant, and its fine, large, blue flowers are a splendid sight. Among them I found the fruit of Asclepias tuberosa. …
181. Acalypha Virginica, L. Three-seeded Mercury.
182. Bidens connata, Muhl. Swamp Beggar-ticks.
183. Solidago nemoralis, Ait. Old field Golden Rod.
184. Gnaphalium polycephalum, Mx. Common Everlasting. [*G. obtusifolium*]
185. Aster cordifolius, L. Cordate-leaved Aster. [*Symphyotrichum cordifolium* (L.) Nesom]
187. Aster linariifolius, L. [*Ionactis l.* (L.) Greene]
188. [Aster] Novae-Angliae, L. New England Aster. [*Symphyotrichum n.* (L.) Nesom]
189. [Aster] multiflorus, Ait. Many-flowered [Aster]. [*Symphyotrichum ericoides* (L.) Nesom]
190. [Aster] umbellatus, Mill. [*Doellingeria umbellata* (P.Mill.) Nees]
191. [Aster] diffusus, Ait. Diffuse [Aster]. [*Symphyotrichum lateriflorum* (L.) A.&D.Love]
192. [Aster] paniculatus, Lam. Panicled [Aster]. [*Symphyotrichum lanceolatum* (Wieg.) Nesom]
194. Solidago caesia, L. Bluish Golden Rod.
195. [Solidago] Canadensis, L. Canada [Golden Rod].
196. [Solidago] serotina, Ait. [*S. gigantea* Ait.]

Interpretation of text

Of the 197 species of vascular plants documented by the Ruths, 97 were native herbaceous species typical of grasslands and meadows (Latham and Rhoads 2006). They also identified 30 nonnative herbaceous species at the site, but in low numbers, in strong contrast to the overwhelming dominance of nonnative species in the site's herbaceous layer today (White and Rhoads 1996).

John Harshberger's description of serpentine grasslands, 1903, and comments on early colonial era natural meadows, 1904

Background

Dr. John William Harshberger (1869–1929), professor of botany at the University of Pennsylvania from 1893 until his death in 1929, had a strong interest in geology, ecology and biogeography, unlike most of his predecessors in the position back to Dr. Adam Kuhn (1741–1817), the first botany professor in America (Harshberger 1899), whose primary field was medicine and whose interest in botany was chiefly utilitarian.

Original text excerpts, 1903

From Harshberger's 1903 article in *Science*, "The flora of the serpentine barrens of southeast Pennsylvania":

> The flora of the serpentine exposures, which are always more or less barren in appearance, is peculiar. The eye of the botanist, or of the observant layman, is at once arrested by the association of the characteristic species which make up the serpentine flora, because it is sharply demarcated from the flora of the surrounding country. The botanist can identify the serpentine areas, where the rock is covered by a shallow soil, by the vegetation alone, for the species which are character plants; although occurring elsewhere in the region, are here grouped together in such a manner and in such number, as to delimit sharply these areas from the surrounding country. The serpentine plants taken together, therefore, form islands set down in a sea of other vegetation with a boundary as well characterized as the shore of an oceanic island, and with tension lines induced by the struggle for existence as sharply drawn as the shore line against which the storm waves beat. This sharp delimitation of the boundaries of the serpentine areas is emphasized by the fact that these areas are rarely cultivated, but are surrounded by rich cultivable land from which the original vegetation has been removed by man. Many of the plants found on the serpentines have survived, therefore, such vicissitudes and have persisted on the barrens, while the same species have been exterminated in the cleared land. …
>
> Several plant associations are recognizable, so that an ecologic classification of the plants is as follows: …
>
> BARREN TREELESS FORMATION.
>
> *Cerastium Association.*
>
> *Phlox Association.*

Deschampsia Association.

Carex-Eleocharis Association.

Spiraea Association.

Rosa Association.

Rubus Association.

Kalmia Association.

Smilax Association. ...

B. SERPENTINE IN THE VALLEY, WEST OF BLACK HORSE HOTEL.

Here is found a typical exposure of serpentine rock. The barren treeless areas (BARREN TREELESS FORMATION) are characterized by the clumps of *Cerastium oblongifolium* Torr. [*Cerastium arvense* L. var. *oblongifolium* Holl & Britt.] (*Cerastium Association*), *Panicum latifolium* L., *Rumex acetosella* L., *Trifolium repens* L. Near by on somewhat similar barren areas occur thickets of green briars *Smilax rotundifolia* L., *Smilax glauca* Walt. with *Juniperus Virginiana* L. and, *Nyssa sylvatica* Marsh rising out, as solitary specimens, from the tangled mass of briars (*Smilax Association*). *Rubus villosus* Ait? (Gray) [*R. nigrobaccus* Bailey], *Rosa lucida* Ehrh. and *Spirea salicifolia* L. form pure growths' (*Rubus, Rosa, Spiraea Associations*), while separating these are grassy stretches, where the botanist finds (*Enothera fruticosa* L. [*Kneiffia fruticosa* (L.) Raimann], *Cerastium oblongifolium* Torr., *Arabis lyrata* L., *Deschampsia caespitosa* Beauv. (*Deschampsia Association*), *Sisyrynchium angustifolium* Mill., *Senecio aureus* L. var. *balsamitea* Torr. & Gray [*Senecio balsamitae* Muhl.], *Geranium maculatum* L. …

D. SERPENTINE AT WILLIAMSON SCHOOL.

The dominant trees on the serpentine barrens at Williamson School are *Quercus alba* L., *Quercus rubra* L., *Quercus stellata* Wang. [*Q. minor* (Marsh.) Sarg.], *Quercus nigra* L. [*Q. marylandica* Muench.], *Acer rubrum* L., and *Juniperus virginiana* L., while associated with these trees are *Sassafras officinale* Nees [*S. sassafras* (L.) Karst.], *Rhus glabra* L., *Kalmia latifolia* L. (*Kalmia Association*), *Salix tristis* Ait., and as lianes, *Vitis aestivalis* Michx., *Ampelopsis quinquefolia* Michx. [*Parthenocissus quinquefolia* (L.) Planch.] and *Smilax rotundifolia* L. The following herbaceous plants grow on the barrens here, *Pteris aquilina* L. [*Pteridium aquilinum* (L.) Kuhn], *Senecio aureus* L. var. *balsamitae* Torr. & Gray [*Senecio balsamitae* Muhl.], *Geranium maculatum* L., *Trifolium agrarium* L. [*Trifolium aureum* Poll.], *Aspidium acrostichoides* Swartz [*Dryopteris acrostichoides* (Michx.) Kuntze] and *Castilleia coccinea* Spreng [(L.) Spreng]. … The barren at the Williamson School is noted for a growth of laurel, *Kalmia latifolia* L., dwarf willow, *Salix tristis* Ait., and until recently was visited by botanists for the scarlet painted-cup, *Castilleia coccinea* Spreng [(L.) Spreng].

E. SERPENTINE AT NEWTOWN SQUARE.

… The treeless barrens support *Cerastium oblongifolium* Torr., *Senecio aureus* L. var. *balsamitae* Torr. & Gray [*Senecio balsamitae* Muhl.] and *Erigeron* Pers. [(L.) Pers.] (BARREN TREELESS FORMATION. *Cerastium Association*).

F. EAST SIDE CRUM CREEK ALONG PRESTON RUN.

A large part of this exposure is treeless, and upon the broken-down serpentine rock grow mats of *Phlox subulata* L. (*Phlox Association*), *Trifolium agrarium* L. [*T. aureum* Poll.] *Pteris aquilina* L. [*Pteridium aquilinum* (L.) Karst.], *Verbascum blattaria* L., *Panicum latifolium* L., *Potentilla canadensis* L. and *Cerastium oblongifolium* Torr. (*Cerastium Association*). …

A study of the flora of these rocky exposures reveals the fact that the same association of species is not found on all of the serpentine barrens. The several component species differ as the localities differ, although the same general character of the vegetation is preserved by the presence of several dominant plants, found on all of the barrens. … Where the ground is too barren to support trees, which usually grow in situations where there is considerable surface soil, the green briar, *Smilax rotundifolia* L. associated with *Smilax glauca* Walt. covers the ground with a dense growth separated by intervals of grass, where the botanist finds the small sundrops, (*Enothera fruticosa* L. [*Kneiffia fruticosa* (L.) Raimann], tufted hair grass, *Deschampsia ccespitosa* Beauv., associated with the blackberry, *Rubus villosus* Ait? (Gray) [*R. nigrobaccus* Bailey], and meadow-sweet, *Spiraea salicifolia* L. These treeless areas can be distinguished at a distance by the clumps of briars, by the presence of sentinel-like red cedars, and by an occasional sour-gum tree.

Interpretation of 1903 text

Harshberger painted a vivid picture of the high degree of patchiness in grassland and meadow vegetation within sites and of the distinctive differences in species composition among sites, even those separated by short distances.

Original text excerpts, 1904

Part of Harshberger's 1904 article, "A phyto-geographic sketch of extreme southeastern Pennsylvania," introducing a section on the flora of uncultivated fields (Harshberger 1904, p. 151):

> From early historic accounts of the region, the original forest was interspersed with open glades and natural meadows where for some edaphic reason the trees did not grow. These areas (such as we have left in the "Indian clearing" near Lima, Delaware County, and in the Playwicky clearing in Bucks County) were settled upon first, and with the exception of the areas above mentioned [under "serpentine-barren treeless formation"] we have no natural openings that have not been altered by the hand of man. The botanist, therefore, has no data upon which to base a statement of the plant covering of such open, treeless areas.

Interpretation of 1904 text

Harshberger's assumption that trees were absent from scattered "open glades and natural meadows" at the time of the earliest writings because of "some edaphic reason" was unsubstantiated. It most likely reflects certain biases common to the earliest ecologists, who lived in the late nineteenth and early twentieth centuries. First, understanding of the importance of disturbance and other historical factors to plant community composition and dynamics was rudimentary at best. Second, the idea that American Indians might have had a strong and lasting influence on the landscape, by whatever means, was virtually nonexistent. Furthermore, at the time this article was published Harshberger doubtless was the most knowledgeable of any scientist in eastern North America on the serpentine grasslands, which served as a dramatic model for edaphic limitation of tree growth.

Francis Pennell's description of the serpentine grasslands of southeastern Pennsylvania and northern Delaware, 1910

Background

Dr. Francis Whittier Pennell (1886–1952), curator of botany at the Philadelphia Academy of Natural Sciences, was the foremost twentieth-century botanical authority on Pennsylvania's serpentine barrens.

Original text excerpts

Part of an introduction preceding detailed floristic descriptions of serpentine grasslands and other serpentine barrens communities (Pennell 1910, pp. 543, 544, 548):

> ... the Barrens lie in two main divisions: to the northeast they are small and scattered (Chester Group), to the southwest they form essentially one long continuous area (State-line Barrens). In the former are some 10 or 12 well-marked exposures, ranging from less than one-half acre (e.g., Sconnelltown) to such as the Serpentine Ridge, three to four miles long. These areas lie near together in extreme southern Montgomery, Delaware, southeastern Chester Counties, Pennsylvania, and northwestern New Castle County, Delaware. They are separated some twenty miles from the nearest point of the State-line Barrens. The latter extends as one ridge, some thirty-five miles long, with a width of one to three miles, trending west-southwest from Little Elk Creek, Chester County, Pennsylvania, through northern Cecil County, Maryland, and over the Susquehanna River into Harford County, Maryland. With this area are allied smaller side areas in southern Lancaster County, Pennsylvania, near the Conowingo Creek.
>
> The areas from which specimens have been examined are: Chester Group: Delaware County—1. Fawkes Run (Newtown). 2. Preston Run. 3. Bear Hill. 4. Blue Hill. 5. Middletown Township (Mineral Hill, Barrens of Middletown, Williamson, Lenni, Wawa). Chester County—6. Sugartown Barrens and Serpentine Ridge. 7. Cedar Barrens. 8. West Chester Barrens (Fern Hill). 9. Sconnelltown and Strode's Mill. 10. Brinton's Quarry. 11. Marshallton (specimens noted collected by B. Long). 12. Unionville. State-line Group: 13. Nottingham Barrens (Nottingham Station to Goat Hill). 14. A few other specimens, mainly collected by J. J. Carter, are cited from points in southern Lancaster County.
>
> The following list shows 217 [245] species composing the characteristic flora of the Conowingo [serpentine] Barrens, while some 77 [104] others were collected occasionally. Of the characteristic species 17 in this section of the Piedmont area are quite or nearly confined to these barrens, while 48 [56] others occur mainly here. The remaining species belong to the normal flora of the district … Many of the

> species occurring mainly on the Conowingo Barrens occur also on other barren (xerophytic) formations of the district, as the South Valley Hill (shale) and the North Valley Hill (quartzite and sandstone). [Numbers in brackets are revised totals, including species added in a follow-up paper two years later (Pennell 1912)]

Interpretation of text

Pennell described 245 plant species as characteristic of the serpentine barrens in the western and southwestern suburbs of Philadelphia, 17 of which he seldom or never found in other habitats locally (Pennell 1910, 1912). Serpentine barrens were far more numerous and extensive a century ago than they are today. Pennell (1910) and Harshberger (1903) described ten serpentine barrens areas in Delaware County, Pennsylvania, but now there is just one (Latham 2008). Six serpentine barrens have also been destroyed in Chester County, Pennsylvania, and another in New Castle County, Delaware. All 16 of these sites were lost to development. Besides the one remaining site in Delaware County, eight serpentine barrens still persist in Chester County and two in Lancaster County, Pennsylvania. Elsewhere there are four serpentine barrens in Maryland, two or three small sites on Staten Island, New York, and one site each in North Carolina and Georgia.

Besides the loss of about half of the total number of serpentine barrens sites, the area of grassland at each site shrank at an ever-increasing rate during the latter half of the twentieth century. This process began with the advent of rural fire suppression, which allowed forest succession to proceed inward from the edges of the serpentine grasslands. Shrinking habitat has meant shrinking populations of grassland species, which in turn has led to dramatic rates of extirpation (Latham 2008; R. E. Latham, unpublished data). Comparisons of Pennell's site surveys (1910, 1912) and other past botanical records with recent surveys have shown drastic declines in grassland species richness at the remnant serpentine grasslands; for instance, at the one remaining serpentine grassland in Delaware County, which has declined from 5.6 ha (14 acres) in 1937 to 1.2 ha (3 acres) today, at least 93 plant species documented as occurring historically were not found in a 2008 survey (Latham 2008).

Appendix C. The Present and Historical Vascular Flora of Valley Forge Grasslands and Meadows

Appendix C. The Present and Historical Vascular Flora of Valley Forge Grasslands and Meadows

The flora consists of taxa (species, subspecies and varieties) confirmed present in 1991–2007 in grasslands and meadows within park boundaries (Newbold 1991–1997; Heister 1994, 1997; Podniesinski et al. 2005; Furedi 2008) and native grassland/ meadow specialists documented in major herbaria as occurring historically at or adjacent to Valley Forge (Pennsylvania Flora Project 2007; T. A. Block, personal communication). It encompasses 566 taxa in 291 genera in 83 families (for a description and summary of the flora, see pp. 35-36 under *Results*).

There are 425 native and 141 nonnative species on the list, including 220 native species confirmed present in the park in 1991–2007. Of the natives on the list, those that are grassland/meadow specialists (Rhoads and Block 2007; see *Methods*, pp. 22-23, for criteria) number 333 species, 172 of which were documented in the park in 1991–2007.

Nomenclature follows Rhoads and Block (2007), which is also the source for origin, growth form and grass photosynthesis type. Pennsylvania Biological Survey status is from the Pennsylvania Natural Heritage Program (2010b; S. Grund, personal communication).

INDEX to the plants listed in Appendix A begins on page 187.

Green highlighting: native grassland and meadow specialists

Origin:

N	native
I	nonnative (introduced)
II	nonnative (introduced) and highly invasive

Pennsylvania Biological Survey status, 2010:

PX	extirpated in the state
PE	endangered in the state
PT	threatened in the state
PR	rare in the state
SP	special population deserving protection that does not fall into another category
TU	tentatively believed to be declining or imperiled but data currently insufficient; under study

Growth form:

HA	herbaceous annual
HB	herbaceous biennial
VA	herbaceous annual vine
HP	herbaceous perennial
VP	herbaceous perennial vine
SD	deciduous shrub
VW	woody vine
TD/TE	deciduous/evergreen tree

C_3 or C_4 (grasses only):

C_3	cool-season grass
C_4	warm-season grass

Documented historically:

HIST	documented historically in or near Valley Forge by herbarium record

Present-day occurrence source:

D	Draude (2008)
F	Furedi (2008)
P	Podniesinski et al. (2000)
N	Newbold (1991–1997)
H	Heister (1994, 1997)

Percent frequency in 2007 (Furedi 2008):

% of 175 survey plots where present in 2007

Mean percent cover in 2007 (Furedi 2008):

% cover averaged over all 175 survey plots in 2007

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
CLUBMOSSES AND FERNS									
EQUISETACEAE									
Equisetum arvense	field horsetail, devil's-guts	N		HP		HIST	F	0.57%	0.003%
OPHIOGLOSSACEAE									
Botrychium dissectum	cutleaf grape-fern	N		HP		HIST	F, P	0.57%	0.001%
POLYPODIACEAE									
Asplenium platyneuron	ebony spleenwort	N		HP		HIST			
Dennstaedtia punctilobula	hay-scented fern, eastern hay-scented fern	N		HP		HIST			
Onoclea sensibilis	sensitive fern	N		HP		HIST	F, P	0.57%	0.003%
Pteridium aquilinum	northern bracken fern	N		HP		HIST			
Thelypteris palustris	marsh fern, eastern marsh fern	N		HP		HIST			
SELAGINELLACEAE									
Selaginella apoda	meadow spikemoss	N		HP		HIST			
CONIFERS									
CUPRESSACEAE									
Juniperus virginiana	eastern red-cedar	N		TE		HIST	F	6.25%	0.024%
PINACEAE									
Pinus rigida	pitch pine	N		TE		HIST			
FLOWERING PLANTS I—MONOCOTS (MISCELLANEOUS)									
ALISMATACEAE									
Alisma subcordatum	broadleaf water-plantain, American water-plantain	N		HP		HIST			
Sagittaria australis	Appalachian arrowhead, longbeak arrowhead	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
ALLIACEAE									
Allium canadense	wild onion, meadow garlic	N		HP		HIST	H		
Allium vineale	field garlic, wild garlic, scallions	I		HP		HIST	F, P, N, H	42.05%	0.196%
ASPARAGACEAE									
Asparagus officinalis	garden asparagus	I		HP			F		
HYACINTHACEAE									
Ornithogalum umbellatum	star-of-Bethlehem, sleepy-dick	I		HP		HIST	N		
HYPOXIDACEAE									
Hypoxis hirsuta	yellow star-grass, common goldstar	N		HP		HIST			
IRIDACEAE									
Iris pseudacorus	yellow iris, water flag	I		HP			F		
Sisyrinchium angustifolium	narrowleaf blue-eyed-grass	N		HP		HIST	F	7.39%	0.056%
Sisyrinchium mucronatum	needletip blue-eyed-grass	N		HP		HIST	N		
LILIACEAE									
Erythronium americanum	yellow trout-lily, dogtooth-violet	N		HP		HIST			
Lilium canadense ssp. *canadense*	Canada lily	N		HP		HIST			
MELANTHIACEAE									
Chamaelirium luteum	devil's-bit, fairy-wand	N		HP		HIST			
ORCHIDACEAE									
Platanthera lacera	ragged fringed-orchid, green fringed-orchid	N		HP		HIST	F		
Spiranthes lacera var. *gracilis*	southern slender ladies'-tresses, northern slender ladies'-tresses	N		HP		HIST			
Spiranthes ochroleuca	yellow nodding ladies'-tresses	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
RUSCACEAE									
Polygonatum biflorum var. *biflorum*	smooth Solomon's-seal	N		HP		HIST			
Polygonatum pubescens	hairy Solomon's-seal	N		HP		HIST			
SMILACACEAE									
Smilax rotundifolia	bullbrier, greenbrier, roundleaf greenbrier	N		VW		HIST			
FLOWERING PLANTS II—COMMELINID MONOCOTS									
CYPERACEAE									
Carex aggregata	glomerate sedge	N		HP		HIST	F, N	1.14%	0.047%
Carex albolutescens	green-white sedge	N		HP			N		
Carex amphibola	eastern narrowleaf sedge	N		HP		HIST	F, N	1.70%	0.019%
Carex annectens	yellow-fruited sedge	N		HP		HIST	F, P, N	7.39%	0.067%
Carex blanda	eastern woodland sedge	N		HP		HIST	F, N, H	2.84%	0.011%
Carex bushii	Bush's sedge	N		HP			F, P, N	14.20%	0.796%
Carex caroliniana	Carolina sedge	N		HP		HIST	F, N	2.27%	0.183%
Carex cephalophora	oval-headed sedge, oval-leaf sedge	N		HP		HIST	F, N	23.86%	0.366%
Carex communis	fibrous-root sedge, colonial oak sedge	N		HP		HIST			
Carex conjuncta	soft fox sedge	N	SP	HP			F, N	1.70%	0.031%
Carex crinita var. *crinita*	short-hair sedge, fringed sedge	N		HP		HIST			
Carex cristatella	crested sedge	N		HP			F, N	0.57%	0.001%
Carex digitalis	slender woodland sedge	N		HP		HIST	F, N	0.57%	0.001%
Carex festucacea	fescue sedge	N		HP		HIST	N		
Carex frankii	Frank's sedge	N		HP		HIST	F, N		
Carex glaucodea	blue sedge	N		HP		HIST	F, N	0.57%	0.001%
Carex gracilescens	slender loose-flowered sedge	N		HP			N		

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Carex granularis var. *granularis*	limestone meadow sedge	N		HP			F, N		
Carex grisea	inflated narrowleaf sedge	N		HP			F		
Carex hirsutella	fuzzy-wuzzy sedge	N		HP		HIST	F, P, N	7.95%	0.149%
Carex hirtifolia	pubescent sedge	N		HP		HIST	N		
Carex intumescens	greater bladder sedge	N		HP		HIST			
Carex jamesii	James' sedge	N	SP	HP		HIST	N		
Carex laevivaginata	smoothsheath sedge	N		HP		HIST	N		
Carex laxiflora	broad loose-flowered sedge	N		HP			N		
Carex leavenworthii	Leavenworth's sedge	N	SP	HP		HIST	F	0.57%	0.003%
Carex lurida	lurid sedge, shallow sedge	N		HP		HIST	F, N		
Carex mesochorea	midland sedge	N		HP			F, N		
Carex muhlenbergii	Mühlenberg's sedge	N		HP		HIST	F, N	1.14%	0.060%
Carex nigromarginata	black-edge sedge	N	SP	HP		HIST			
Carex normalis	greater straw sedge	N		HP		HIST	F, N		
Carex pallescens	pale sedge	N		HP			N		
Carex radiata	eastern star sedge	N		HP		HIST	F, N	2.27%	0.129%
Carex rosea	rosy sedge	N		HP			N		
Carex scoparia	broom sedge	N		HP			F, N	0.57%	0.003%
Carex sparganioides	bur-reed sedge	N		HP		HIST			
Carex spicata	prickly sedge	I		HP			F, N	17.61%	0.301%
Carex stipata var. *stipata*	stalk-grain sedge, owlfruit sedge	N		HP		HIST	F, N		
Carex swanii	downy green sedge, Swan's sedge	N		HP		HIST	F, P, N	2.84%	0.023%
Carex tonsa var. *tonsa*	shaved sedge	N	SP	HP		HIST			
Carex vulpinoidea	fox sedge, brown fox sedge	N		HP		HIST	F, N	1.14%	0.017%
Cyperus acuminatus	short-pointed flatsedge, taper-tip flatsedge	N		HA			F	0.57%	0.003%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Cyperus bipartitus	slender flatsedge	N		HA		HIST			
Cyperus esculentus	yellow nutsedge	N		HP		HIST	F, N		
Cyperus lupulinus	Great Plains flatsedge, sand sedge	N		HP		HIST	P		
Cyperus odoratus	rusty flatsedge, fragrant flatsedge	N		HA		HIST			
Cyperus strigosus	straw-colored flatsedge, false nutsedge	N		HP		HIST	N		
Eleocharis engelmannii	Engelmann's spike-rush	N	SP	HA		HIST			
Eleocharis obtusa var. *obtusa*	Wright's spike-rush, blunt spike-rush	N		HA		HIST			
Eleocharis tenuis var. *tenuis*	slender spike-rush	N		HP			F		
Fimbristylis autumnalis	slender fimbry	N		HA		HIST			
Schoenoplectus tabernaemontani	great bulrush, soft-stem bulrush	N		HP		HIST			
Scirpus expansus	wood bulrush, woodland bulrush	N		HP		HIST			
Scirpus georgianus	Georgia bulrush	N		HP		HIST			
Trichophorum planifolium	club-rush, bashful bulrush	N		HP		HIST			
JUNCACEAE									
Juncus acuminatus	sharp-fruited rush, tapertip rush	N		HP			F		
Juncus effusus var. *pylaei*	soft rush, common rush	N		HP			N		
Juncus effusus var. *solutus*	soft rush, lamp rush	N		HP			F		
Juncus tenuis var. *tenuis*	path rush, poverty rush	N		HP		HIST	F, P, N	16.48%	0.161%
Luzula echinata	common woodrush, hedgehog woodrush	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
POACEAE									
Agrostis gigantea	redtop	I		HP	C_3	HIST	F, P, N	52.27%	4.174%
Agrostis perennans	autumn bentgrass, upland bentgrass, autumn bent, upland bent	N		HP	C_3	HIST	F	2.27%	0.034%
Agrostis stolonifera var. *palustris*	carpet bentgrass, creeping bentgrass	I		HP	C_3		F, P, N, H	0.57%	0.046%
Andropogon gerardii	big bluestem, turkeyfoot	N		HP	C_4	HIST	F, N		
Andropogon glomeratus	bushy bluestem	N	PR	HP	C_4	HIST	D		
Andropogon gyrans	Elliott's beardgrass, Elliott's bluestem	N	PR	HP	C_4		F, N	15.34%	0.554%
Andropogon virginicus	broomsedge, broomsedge bluestem	N		HP	C_4	HIST	F, P, N	68.18%	10.127%
Anthoxanthum odoratum	sweet vernalgrass	I		HP	C_3	HIST	F, P, N, H	69.32%	15.049%
Aristida longespica var. *longespica*	slender three-awn, slimspike three-awn	N	TU	HA	C_4	HIST	N		
Aristida oligantha	prairie three-awn	N		HA	C_4	HIST	F	1.14%	0.017%
Arrhenatherum elatius var. *biaristatum*	tall oatgrass	I		HP	C_3		F, N, H	13.64%	2.370%
Arthraxon hispidus	small carpgrass	I		HA	C_4		N		
Bromus commutatus	hairy chess	I		HA	C_3	HIST	F, P	11.36%	1.964%
Bromus inermis	smooth brome	I		HP	C_3		F, N	0.57%	0.014%
Bromus japonicus	Japanese chess	I		HA	C_3		F, N	2.84%	0.271%
Bromus sterilis	barren brome, poverty brome	I		HA	C_3		F	1.14%	0.220%
Bromus tectorum	downy chess, cheatgrass	I		HA	C_3		N		
Chloris verticillata	windmill-grass, tumble windmill-grass	I		HP	C_4		F, N	1.14%	0.123%
Cynodon dactylon	Bermudagrass, wiregrass	I		HP	C_4	HIST	F	1.14%	0.091%
Dactylis glomerata	orchardgrass	I		HP	C_3	HIST	F, P, N, H	50.57%	4.990%
Danthonia compressa	northern oatgrass, flattened oatgrass	N		HP	C_3	HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Danthonia spicata	poverty-grass, poverty oatgrass	N		HP	C_3	HIST	F, N	2.84%	0.283%
Deschampsia flexuosa	wavy hairgrass, common hairgrass	N		HP	C_3	HIST			
Dichanthelium acuminatum	tapered rosette grass, Lindheimer panic-grass	N		HP	C_3	HIST	F, P, N, H	40.34%	0.707%
Dichanthelium boscii	Bosc's panic-grass	N		HP	C_3	HIST			
Dichanthelium clandestinum	deer-tongue, deer-tongue grass	N		HP	C_3		F, N, H	5.68%	0.197%
Dichanthelium commutatum ssp. *commutatum*	oval-leaf panic-grass, variable panic-grass	N		HP	C_3	HIST			
Dichanthelium depauperatum	poverty panic-grass, starved panic-grass	N		HP	C_3	HIST			
Dichanthelium dichotomum	cypress panic-grass	N		HP	C_3	HIST	N		
Dichanthelium linearifolium	slimleaf witchgrass, slimleaf panic-grass	N		HP	C_3	HIST			
Digitaria cognata	fall witchgrass	N		HP	C_4	HIST	F, N	1.14%	0.029%
Digitaria filiformis	slender crabgrass	N	SP	HA	C_4		N		
Digitaria ischaemum	smooth crabgrass	I		HA	C_4	HIST	F, N	6.82%	0.429%
Digitaria sanguinalis	northern crabgrass, hairy crabgrass	I		HA	C_4	HIST	F, N	1.70%	0.246%
Echinochloa crusgalli var. *crusgalli*	barnyard-grass	I		HA	C_4	HIST	F, N	1.14%	0.004%
Echinochloa muricata	rough barnyard-grass, cockspur	N		HA	C_4	HIST	F, P		
Eleusine indica	goosegrass, Indian goosegrass, wiregrass	I		HA	C_4	HIST	F, N		
Elymus canadensis var. *canadensis*	Canada wild-rye	N		HP	C_3	HIST			
Elymus hystrix	bottlebrush-grass, eastern bottle-brush grass	N		HP	C_3		F, N, H		

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Elymus repens	quackgrass	I		HP	C_3	HIST	F, P, N	25.57%	4.363%
Elymus riparius	riverbank wild-rye	N		HP	C_3	HIST	N		
Elymus villosus	hairy wild-rye	N		HP	C_3	HIST			
Elymus virginicus	Virginia wild-rye	N		HP	C_3	HIST	F	0.57%	0.014%
Eragrostis capillaris	lacegrass	N		HA	C_4	HIST			
Eragrostis cilianensis	stinkgrass	I		HA	C_4		N		
Eragrostis frankii	sandbar lovegrass	N		HA	C_4	HIST			
Eragrostis hypnoides	creeping lovegrass, teal lovegrass	N		HA	C_4	HIST			
Eragrostis pectinacea	Carolina lovegrass, tufted lovegrass	N		HA	C_4	HIST	N		
Eragrostis spectabilis	purple lovegrass, tumblegrass	N		HP	C_4	HIST	F, P, N, H	15.91%	0.379%
Festuca obtusa	nodding fescue	N		HP	C_3	HIST			
Festuca rubra	red fescue	I		HP	C_3	HIST	F, P, N, H	42.61%	9.851%
Glyceria septentrionalis	floating mannagrass	N		HP	C_3	HIST			
Glyceria striata	fowl mannagrass	N		HP	C_3		F		
Holcus lanatus	velvetgrass	I		HP	C_3	HIST	F, N		
Leersia oryzoides	rice cutgrass	N		HP	C_3	HIST	F, N		
Leersia virginica	whitegrass	N		HP	C_3	HIST	F, N		
Lolium multiflorum	ryegrass	I		HP	C_3		F, N		
Lolium perenne	perennial ryegrass	I		HP	C_3		F, N	7.39%	0.121%
Microstegium vimineum	stiltgrass, Japanese stiltgrass, Nepalese browntop	II		HA	C_4		F, P, N, H	56.82%	17.907%
Miscanthus sinensis var. *sinensis*	eulalia, Chinese silvergrass	II		HP	C_4		F, N	1.14%	0.049%
Muhlenbergia frondosa	wirestem muhly	N		HP	C_4	HIST	F		
Muhlenbergia schreberi	nimble-will, dropseed	N		HP	C_4	HIST	F, N, H	26.14%	2.010%
Panicum anceps	beaked panic-grass	N		HP	C_4	HIST	F, P, N, H	40.91%	8.264%
Panicum capillare	witchgrass	N		HA	C_4		N, H		

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Panicum dichotomiflorum	smooth panic-grass, fall panic-grass	N		HA	C_4	HIST	F, N		
Panicum philadelphicum	Philadelphia panic-grass	N		HA	C_4	HIST			
Panicum rigidulum	redtop panic-grass	N		HP	C_4		F, N, H		
Panicum virgatum	switchgrass	N		HP	C_4	HIST	F		
Paspalum laeve	field beadgrass, field paspalum	N		HP	C_4		F, H	15.34%	0.510%
Paspalum setaceum var. *muhlenbergii*	slender beadgrass, thin paspalum	N	TU	HP	C_4	HIST	F, P, N	15.91%	0.127%
Phalaris arundinacea	reed canary-grass	II*		HP	C_3		F, P, N		
Phleum pratense	timothy	I		HP	C_3	HIST	F, P, N, H	17.05%	1.350%
Phragmites australis ssp. *australis*	common reed, phrag	II		HP	C_3		F		
Poa annua	annual bluegrass	I		HA	C_3	HIST	F, N	0.57%	0.014%
Poa compressa	Canada bluegrass	I		HP	C_3	HIST	F, N	10.23%	0.493%
Poa pratensis	Kentucky bluegrass	I		HP	C_3	HIST	F, P, N, H	77.84%	12.406%
Poa trivialis	rough bluegrass	I		HP	C_3	HIST	F, N, H	7.95%	0.833%
Schedonorus pratensis	meadow fescue	I		HP	C_3		F, P, N, H	70.45%	17.400%
Schizachyrium scoparium var. *scoparium*	little bluestem	N		HP	C_4	HIST	F, N	4.55%	0.190%
Setaria faberi	giant foxtail, Japanese bristle-grass	I		HA	C_4	HIST	F, N, H	8.52%	0.547%
Setaria parviflora	perennial foxtail, marsh bristle-grass	N		HP	C_4		F, P, N, H	67.61%	3.664%
Setaria pumila	yellow foxtail	I		HA	C_4	HIST	F, N	54.55%	2.429%
Setaria viridis var. *viridis*	green foxtail, green bristle-grass	I		HA	C_4	HIST	N		
Sorghastrum nutans	Indian-grass	N		HP	C_4	HIST	F	0.57%	0.046%

* *Phalaris arundinacea* is native to North America and Eurasia. Most wild plants here are thought to be descended from Eurasian stock planted as forage. Some Eurasian genotypes are aggressively invasive and cannot be reliably distinguished from native genotypes. It should be treated as a nonnative species.

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Sphenopholis nitida	shining wedgegrass, shiny wedgescale	N		HP	C_3	HIST			
Sporobolus vaginiflorus	poverty dropseed	N		HA	C_4		F		
Torreyochloa pallida var. *pallida*	pale meadowgrass, pale false mannagrass	N		HP	C_3	HIST			
Tridens flavus	purpletop	N		HP	C_4	HIST	F, P, N, H	68.18%	8.864%
Tripsacum dactyloides	gammagrass, eastern gamagrass	N	PE	HP	C_3		F		
Vulpia myuros var. *myuros*	foxtail fescue, rat-tail fescue	I		HA	C_3		F		
Vulpia octoflora var. *glauca*	six-weeks fescue	N		HA	C_3	HIST			
SPARGANIACEAE									
Sparganium androcladum	branching bur-reed, branched bur-reed	N	PE	HP	BEC		P		
TYPHACEAE									
Typha latifolia	common cat-tail, broadleaf cat-tail	N		HP		HIST	F		
FLOWERING PLANTS III—MAGNOLIIDS									
LAURACEAE									
Lindera benzoin	spicebush	N		SD			F		
Sassafras albidum	sassafras	N		TD		HIST	F		
MAGNOLIACEAE									
Liriodendron tulipifera	tuliptree, yellow-poplar	N		TD		HIST	F	7.95%	0.021%
FLOWERING PLANTS IV—EUDICOTS (MISCELLANEOUS)									
ALTINGIACEAE									
Liquidambar styraciflua	sweetgum	N		TD			F	0.57%	0.014%
AMARANTHACEAE									
Amaranthus albus	prostrate pigweed, tumbleweed	N		HA		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Chenopodium album var. *missouriense*	lamb's-quarters, late-flowering goosefoot	N		HA		HIST			
Chenopodium simplex	maple-leaf goosefoot	N		HA		HIST			
BERBERIDACEAE									
Berberis thunbergii	Japanese barberry	II		SD			F		
CARYOPHYLLACEAE									
Cerastium arvense ssp. *arvense*	field chickweed	N		HP			P		
Cerastium fontanum ssp. *triviale*	common mouse-ear chickweed, big chickweed	I		HP		HIST	F, P, N	28.41%	0.279%
Dianthus armeria	Deptford-pink	I		HB		HIST	F, P	5.68%	0.034%
Silene antirrhina	sleepy catchfly, sleepy silene	N		HA		HIST	F		
Silene latifolia	bladder campion, white campion	I		HA HP		HIST	F	0.57%	0.003%
Silene stellata	starry campion, widow's-frill	N		HP		HIST			
Stellaria media	common chickweed	I		HA		HIST	F, P, H		
Stellaria pubera	great chickweed, star chickweed	N		HP		HIST			
PHYTOLACCACEAE									
Phytolacca americana	pokeweed, American pokeweed	N		HP			F		
POLYGONACEAE									
Fallopia scandens	climbing false buckwheat	N		VP		HIST	F		
Persicaria amphibia	water smartweed	N	SP	HP			F		
Persicaria arifolia	halberd-leaf tearthumb	N		HA			F		
Persicaria hydropiper	smartweed, water-pepper, marsh-pepper knotweed	I		HA		HIST	F	0.57%	0.003%
Persicaria hydropiperoides	mild water-pepper, swamp smartweed	N		HP			P		
Persicaria longiseta	low smartweed	I		HA			F		

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Persicaria pensylvanica	Pennsylvania smartweed, pinkweed	N		HA		HIST	F	0.57%	0.001%
Persicaria perfoliata	mile-a-minute weed, Asiatic tearthumb	II		HA		HIST	F	1.14%	0.003%
Persicaria punctata	dotted smartweed, water smartweed	N		HP		HIST	F	1.14%	0.016%
Persicaria sagittata	arrowleaf tearthumb, scratch-grass	N		HA		HIST	F, P	1.14%	0.110%
Polygonum aviculare	prostrate knotweed	I		HA		HIST	F	1.14%	0.004%
Polygonum erectum	erect knotweed	N		HA		HIST	F		
Rumex acetosella	sheep sorrel, sourgrass	I		HP		HIST	F, P, N	30.11%	0.813%
Rumex crispus	curly dock	I		HP			F, N	3.98%	0.017%
Rumex obtusifolius	bitter dock	I		HP			F		
Rumex verticillatus	swamp dock	N		HP			P		
PORTULACACEAE									
Claytonia virginica	spring-beauty, Virginia spring-beauty	N		HP		HIST			
Portulaca oleracea	purslane, little hogweed	N		HA		HIST			
RANUNCULACEAE									
Anemone virginiana	tall anemone, tall thimbleweed	N		HP		HIST			
Aquilegia canadensis	wild columbine, red columbine	N		HP		HIST			
Clematis virginiana	virgin's-bower, devil's-darning-needles	N		VP		HIST			
Ranunculus bulbosus	bulbous buttercup, St. Anthony's-turnip	I		HP		HIST	F, N	11.36%	0.047%
Ranunculus ficaria	lesser celandine, pilewort, fig buttercup	II		HP		HIST	F	0.57%	0.003%
Thalictrum pubescens	tall meadow-rue, king-of-the-meadow	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
VITACEAE									
Parthenocissus quinquefolia	Virginia-creeper, woodbine	N		VW		HIST	F, H	10.23%	0.037%
FLOWERING PLANTS V—EUDICOTS: ROSIDS (MISCELLANEOUS)									
GERANIACEAE									
Geranium carolinianum	Carolina cranesbill, Carolina geranium, wild geranium	N		HA		HIST	F, H	0.57%	0.001%
Geranium maculatum	wood geranium, spotted geranium	N		HP		HIST			
LYTHRACEAE									
Cuphea viscosissima	blue waxweed, clammy cuphea	N		HA		HIST			
Lythrum salicaria	purple loosestrife	II		HP			F		
Rotala ramosior	tooth-cup, lowland rotala	N	PR	HA		HIST	F		
ONAGRACEAE									
Epilobium coloratum	purple-leaf willow-herb	N		HP		HIST	F		
Gaura biennis	gaura, biennial bee-blossom	N		HA HB		HIST			
Ludwigia alternifolia	seedbox, false loosestrife	N		HP		HIST			
Oenothera biennis	common evening-primrose	N		HB HP			F		
Oenothera fruticosa ssp. *glauca*	sundrops, narrowleaf evening-primrose	N		HP		HIST			
Oenothera perennis	little evening-primrose, sundrops	N		HP			F		
Oenothera pilosella	sundrops, meadow evening-primrose	N		HP		HIST			
FLOWERING PLANTS VI—EUDICOTS: EUROSIDS									
ANACARDIACEAE									
Rhus glabra	smooth sumac	N		SD		HIST			
Toxicodendron radicans	poison-ivy	N		VW		HIST	F, P, N	19.89%	0.167%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
BETULACEAE									
Betula lenta	sweet birch, black birch	N		TD			N		
Betula nigra	river birch	N		TD		HIST			
BRASSICACEAE									
Alliaria petiolata	garlic mustard	II		HB		HIST	F, N	0.57%	0.003%
Arabidopsis thaliana	mouse-ear cress	I		HA		HIST	F	1.70%	0.051%
Arabis laevigata var. *laevigata*	smooth rockcress	N		HB		HIST			
Barbarea vulgaris	common wintercress, garden yellow-rocket	I		HB			F, N	6.25%	0.080%
Brassica rapa	field mustard	I		HA			F	0.57%	0.109%
Capsella bursa-pastoris	shepherd's-purse	I		HA HB			F		
Cardamine hirsuta	hairy bittercress	I		HA			F		
Erysimum cheiranthoides	treacle-mustard, wormseed-mustard, wormseed wallflower	I		HA			F		
Hesperis matronalis	dame's-rocket	I		HP			F		
Lepidium campestre	fieldcress, field pepperweed	I		HA HB		HIST	F	0.57%	0.003%
Lepidium virginicum	poor-man's-pepper, wild pepper-grass, Virginia pepperweed	N		HA HB			F		
Nasturtium officinale	watercress	I		HP			F		
Rorippa palustris	marsh watercress, yellow watercress, bog yellowcress	N		HA HB		HIST			
Thlaspi arvense	field pennycress, frenchweed	I		HA			F		
CANNABACEAE									
Humulus japonicus	Japanese hops	II		HP			F		
Humulus lupulus var. *lupuloides*	brewer's hops, common hops	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Humulus lupulus var. *lupulus*	brewer's hops, common hops	N		HP		HIST			
CELASTRACEAE									
Celastrus orbiculatus	Oriental bittersweet	II		VW			F, P, N, H	61.36%	3.481%
CISTACEAE									
Lechea minor	thyme-leaf pinweed	N	PE	HP		HIST			
CUCURBITACEAE									
Sicyos angulatus	bur cucumber, one-seeded bur cucumber	N		VA		HIST			
ELAEAGNACEAE									
Elaeagnus umbellata	autumn-olive	II		SD		HIST	F, P, N	10.80%	0.437%
EUPHORBIACEAE									
Acalypha gracilens	slender three-seeded mercury	N		HA			F	9.09%	0.034%
Acalypha rhomboidea	common three-seeded mercury	N		HA		HIST	F	2.84%	0.007%
Acalypha virginica	Virginia three-seeded mercury	N		HA		HIST	F	1.70%	0.007%
Euphorbia cyparissias	cypress spurge	I		HP			N		
Euphorbia maculata	spotted spurge, milk-purslane, spotted sandmat	N		HA		HIST			
Euphorbia nutans	eyebane	N		HA		HIST			
Euphorbia vermiculata	hairy spurge	N		HA		HIST			
FABACEAE									
Amorpha fruticosa	indigobush, false-indigo	N		SD		HIST	F		
Amphicarpaea bracteata	American hog-peanut	N		VP VA		HIST	F, P		
Baptisia tinctoria	wild indigo, horseflyweed	N		HP		HIST			
Chamaecrista nictitans	wild sensitive-plant, sensitive partridge-pea	N		HA		HIST	F		
Coronilla varia	crown-vetch	II		HP			F	1.14%	0.006%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Crotalaria sagittalis	rattlebox, arrowhead rattlebox	N		HA		HIST			
Desmodium canescens	hoary tick-trefoil	N		HP		HIST			
Desmodium laevigatum	smooth tick-clover, smooth tick-trefoil	N	TU	HP		HIST			
Desmodium marilandicum	Maryland tick-clover, smooth small-leaf tick-trefoil	N		HP			F	0.57%	0.001%
Desmodium paniculatum	panicled tick-trefoil	N		HP		HIST	P		
Gleditsia triacanthos	honey-locust	N		TD		HIST	F, P	7.95%	0.054%
Kummerowia striata	Japanese clover	I		HA			F	0.57%	0.003%
Lespedeza angustifolia	narrowleaf bush-clover	N	PE	HP			F	0.57%	0.014%
Lespedeza capitata	round-headed bush-clover, round-headed lespedeza	N		HP		HIST			
Lespedeza cuneata	sericea bush-clover, sericea lespedeza	I		HP		HIST	F	1.70%	0.006%
Lespedeza procumbens	trailing bush-clover, trailing lespedeza	N		HP		HIST			
Lespedeza violacea	violet bush-clover, violet lespedeza	N		HP		HIST			
Lespedeza virginica	slender bush-clover, slender lespedeza	N		HP		HIST	F	0.57%	0.003%
Lotus corniculatus	bird's-foot trefoil	I		HP			F, P	0.57%	0.003%
Lupinus perennis	blue lupine, sundial lupine	N	PR	HP		HIST			
Medicago lupulina	black medic	I		HA		HIST	F, P	3.41%	0.023%
Medicago sativa	alfalfa	I		HP		HIST	F	0.57%	0.001%
Melilotus alba	white sweet-clover	I		HB			F		
Melilotus officinalis	yellow sweet-clover	I		HB			F		
Phaseolus polystachios	wild kidney-bean, slimleaf bean	N	PE	VP		HIST			
Robinia pseudoacacia	black locust	N		TD			F	1.70%	0.113%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Senna hebecarpa	northern wild senna, American senna	N		HP		HIST			
Stylosanthes biflora	pencil-flower, sidebeak pencil-flower	N	PE	HP		HIST			
Tephrosia virginiana	goat's-rue, Virginia tephrosia	N		HP		HIST			
Trifolium aureum	large yellow hop-clover, golden clover	I		HA HB		HIST	F, N	3.41%	0.039%
Trifolium campestre	low hop-clover, field clover	I		HA		HIST	F	5.68%	0.309%
Trifolium dubium	little hop-clover, suckling clover	I		HA			F	2.27%	0.034%
Trifolium hybridum	alsike clover	I		HP			F	0.57%	0.001%
Trifolium pratense	red clover	I		HP			F, P, N, H	11.93%	0.087%
Trifolium repens	white clover	I		HP		HIST	F	17.05%	0.601%
Vicia sativa ssp. *sativa*	common vetch, garden vetch, tare	I		HA			F		
Vicia tetrasperma	slender vetch, lentil vetch	I		HA			F	2.84%	0.024%
Fagaceae									
Quercus coccinea	scarlet oak	N		TD		HIST			
Quercus marilandica	blackjack oak	N		TD		HIST			
Quercus rubra	northern red oak	N		TD		HIST	N		
Quercus stellata	post oak	N		TD		HIST			
Hypericaceae									
Hypericum gentianoides	orange-grass, pineweed	N		HA		HIST			
Hypericum mutilum	dwarf St. John's-wort	N		HP		HIST	F	0.57%	0.001%
Hypericum perforatum	common St. John's-wort	I		HP		HIST	F, P	2.27%	0.009%
Hypericum punctatum	spotted St. John's-wort	N		HP		HIST	F		
Hypericum stragulum	St. Andrew's-cross	N	SP	SD		HIST	D		
Juglandaceae									
Juglans nigra	black walnut	N		TD		HIST	F, N		

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
MORACEAE									
Morus alba	white mulberry	I		TD			F	2.84%	0.011%
OXALIDACEAE									
Oxalis dillenii ssp. *filipes*	southern yellow wood-sorrel, slender yellow wood-sorrel	N		HP		HIST			
Oxalis stricta	common yellow wood-sorrel	N		HP			F, P, N	68.18%	0.820%
POLYGALACEAE									
Polygala verticillata var. *ambigua*	whorled milkwort	N		HA		HIST			
ROSACEAE									
Agrimonia gryposepala	tall hairy agrimony, harvest-lice	N		HP		HIST			
Agrimonia rostellata	woodland agrimony, beaked agrimony	N		HP		HIST			
Agrimonia striata	roadside agrimony	N		HP		HIST			
Amelanchier laevis	Allegheny serviceberry, smooth serviceberry, smooth shadbush, smooth juneberry	N		TD		HIST			
Crataegus coccinea	red-fruited hawthorn	N		SD TD		HIST			
Crataegus punctata	dotted hawthorn, white hawthorn	N		TD		HIST			
Crataegus succulenta	long-spined hawthorn, fleshy hawthorn	N		TD		HIST			
Duchesnea indica	Indian strawberry	I		HP		HIST	F, H	2.84%	0.013%
Fragaria virginiana	wild strawberry, Virginia strawberry	N		HP		HIST	F, P, N	1.14%	0.017%
Geum canadense	white avens	N		HP		HIST			
Physocarpus opulifolius	ninebark, common ninebark	N		SD		HIST			
Potentilla canadensis	dwarf cinquefoil	N		HP			F	2.27%	0.010%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Potentilla norvegica ssp. *monspeliensis*	strawberry-weed, Norwegian cinquefoil	N		HA HB		HIST	F		
Potentilla recta	sulphur cinquefoil	I		HP		HIST	F	1.14%	0.003%
Potentilla simplex	old-field cinquefoil, common cinquefoil	N		HP		HIST	F, N	5.11%	0.137%
Prunus americana	wild plum, American plum	N		SD TD		HIST			
Prunus avium	sweet cherry	I		TD			F		
Prunus serotina	black cherry, wild black cherry	N		TD			F	2.27%	0.007%
Prunus virginiana	choke cherry	N		SD TD		HIST	P		
Rosa carolina	pasture rose, Carolina rose	N		SD		HIST			
Rosa multiflora	multiflora rose	II		SD			F, P, N, H	28.41%	0.641%
Rubus allegheniensis	common blackberry, Allegheny blackberry	N		SD			F	2.27%	0.687%
Rubus cuneifolius	sand blackberry	N	PE	SD			D, F		
Rubus hispidus	swamp dewberry, bristly dewberry	N		VW			N, H		
Rubus idaeus var. *strigosus*	red raspberry, American red raspberry	N		SD			F		
Rubus occidentalis	black-cap, black raspberry	N		SD		HIST			
Rubus pensilvanicus	Pennsylvania blackberry	N		SD			N		
Rubus phoenicolasius	wineberry, wine raspberry	I		SD			F, P	0.57%	0.003%
SALICACEAE									
Populus grandidentata	bigtooth aspen	N		TD		HIST			
Salix eriocephala	diamond willow, Missouri River willow	N		SD		HIST			
Salix nigra	black willow	N		TD		HIST			
SAPINDACEAE									
Acer negundo	box-elder	N		TD		HIST	F	2.84%	0.227%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Acer platanoides	Norway maple	II		TD		HIST	F	0.57%	0.217%
Acer rubrum	red maple, swamp maple	N		TD		HIST	F	1.14%	0.003%
SIMAROUBACEAE									
Ailanthus altissima	ailanthus, tree-of-heaven	II		TD		HIST	F, P, N	1.14%	0.003%
URTICACEAE									
Boehmeria cylindrica var. *cylindrica*	false nettle, small-spiked false nettle, stingless nettle	N		HP		HIST	F	0.57%	0.109%
Parietaria pensylvanica	pellitory, Pennsylvania pellitory	N		HA		HIST			
Urtica dioica ssp. *gracilis*	stinging nettle, great nettle	N		HP		HIST	F	0.57%	0.109%
VIOLACEAE									
Viola cucullata	blue marsh violet, marsh blue violet	N		HP		HIST			
Viola labradorica	American dog violet, alpine violet	N		HP		HIST			
Viola sagittata var. *ovata*	arrowleaf violet, ovate-leaf violet	N		HP		HIST			
Viola sororia	common blue violet	N		HP			N, H		
FLOWERING PLANTS VII—EUDICOTS: ASTERIDS (MISCELLANEOUS)									
BALSAMINACEAE									
Impatiens capensis	jewelweed, spotted touch-me-not	N		HA		HIST	F		
CORNACEAE									
Cornus amomum ssp. *amomum*	silky dogwood, kinnikinik, red-willow	N		SD		HIST			
Cornus florida	flowering dogwood	N		TD			F		
Cornus racemosa	gray dogwood	N		SD			F	0.57%	0.003%
ERICACEAE									
Vaccinium angustifolium	lowbush blueberry, low sweet blueberry	N		SD		HIST			
Vaccinium corymbosum	highbush blueberry	N		SD		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Vaccinium pallidum	lowbush blueberry, Blue Ridge blueberry	N		SD		HIST			
Vaccinium stamineum	deerberry	N		SD		HIST			
MYRSINACEAE									
Anagallis arvensis	scarlet pimpernel, poorman's-weatherglass	I		HA		HIST	F	2.84%	0.056%
Lysimachia ciliata	fringed loosestrife	N		HP		HIST			
Lysimachia nummularia	creeping-charlie, moneywort	I		HP			F, N	1.14%	0.006%
Lysimachia quadrifolia	whorled loosestrife, whorled yellow loosestrife	N		HP		HIST			
FLOWERING PLANTS VIII—EUDICOTS: EUASTERIDS									
ACANTHACEAE									
Justicia americana	water-willow, American water-willow	N		HP		HIST			
ADOXACEAE									
Sambucus canadensis	American elder	N		SD		HIST			
Viburnum lentago	nannyberry, sheepberry	N		SD		HIST			
Viburnum prunifolium	black-haw	N		SD TD		HIST			
APIACEAE									
Aegopodium podagraria	goutweed	II		HP			F		
Cicuta maculata var. *maculata*	beaver-poison, musquash-root, spotted cowbane	N		HP		HIST			
Daucus carota	Queen Anne's-lace, wild carrot	I		HB		HIST	F, P, H	9.09%	0.243%
Heracleum lanatum	cow-parsnip	N		HP		HIST			
Pastinaca sativa	wild parsnip	I		HB			F		
Sanicula marilandica	black snakeroot, black sanicle, Maryland sanicle	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Thaspium barbinode	meadow-parsnip	N		HP		HIST			
Zizia aurea	golden-alexander, golden zizia	N		HP		HIST			
APOCYNACEAE									
Apocynum androsaemifolium	spreading dogbane, pink dogbane	N		HP		HIST			
Apocynum cannabinum	Indian-hemp	N		HP		HIST	F, P	44.89%	2.149%
Asclepias incarnata ssp. *pulchra*	swamp milkweed	N		HP		HIST	F		
Asclepias syriaca	common milkweed	N		HP		HIST	F, P, N	41.48%	3.841%
Asclepias tuberosa	butterfly-weed, butterfly milkweed	N		HP			F		
Asclepias viridiflora	green milkweed, green comet milkweed	N		HP		HIST	F	1.14%	0.003%
Matelea obliqua	anglepod, oblique milkvine, climbing milkvine	N	PE	VP		HIST			
Vincetoxicum nigrum	black swallow-wort, Louise's swallow-wort	II		VP			F		
ARALIACEAE									
Hydrocotyle americana	marsh pennywort, American marsh pennywort, navelwort	N		HP		HIST			
ASTERACEAE									
Achillea millefolium	common yarrow, milfoil	I		HP		HIST	F, P, N	24.43%	0.597%
Ageratina altissima var. *altissima*	common white snakeroot	N		HP		HIST	F	23.86%	4.566%
Ambrosia artemisiifolia	common ragweed	N		HA		HIST	F, P	4.55%	0.393%
Anaphalis margaritacea	pearly everlasting	N		HP		HIST	P		
Antennaria howellii	Howell's pussytoes, small pussytoes	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Antennaria neglecta	overlooked pussytoes, field pussytoes	N		HP		HIST	F, N	1.14%	0.006%
Antennaria parlinii	Parlin's pussytoes	N		HP		HIST	F	0.57%	0.003%
Antennaria plantaginifolia	plantain-leaf pussytoes, woman's-tobacco	N		HP		HIST	F, N	2.84%	0.117%
Artemisia annua	sweet wormwood, annual wormwood, sweet sagewort	I		HA			F		
Artemisia vulgaris	common mugwort, common wormwood	II		HP			F	9.66%	4.460%
Baccharis halimifolia	groundsel-tree, eastern baccharis	N	PR	SD		HIST			
Bidens bipinnata	Spanish-needles	N		HA		HIST			
Bidens cernua	nodding beggar-ticks, bur-marigold, stick-tights	N		HA		HIST			
Bidens connata	purple-stemmed beggar-ticks, stick-tights	N		HA		HIST			
Bidens frondosa	devil's beggar-ticks, stick-tights	N		HA		HIST	F		
Bidens tripartita	three-lobed beggarticks	N		HA		HIST			
Brickellia eupatorioides	false boneset	N		HP		HIST			
Carduus nutans	nodding thistle, musk thistle, nodding plumeless thistle	I		HB			F		
Centaurea jacea	brown knapweed, brown-ray knapweed	I		HP			F	3.41%	0.143%
Centaurea stoebe ssp. *micranthos*	spotted knapweed	II		HB			F, H	0.57%	0.014%
Cichorium intybus	blue chicory, blue sailors	I		HP			F		
Cirsium arvense	Canada thistle	II		HP		HIST	F	7.39%	0.886%
Cirsium discolor	field thistle	N		HB HP			F, P	7.95%	0.241%
Cirsium pumilum	pasture thistle	N		HB			F	1.14%	0.016%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Cirsium vulgare	bull-thistle	II		HB		HIST	F	3.98%	0.121%
Conoclinium coelestinum	blue mistflower, wild ageratum	N	SP	HP			F		
Conyza canadensis var. *canadensis*	horseweed, Canadian horseweed	N		HA		HIST	F, P	3.41%	0.036%
Doellingeria infirma	flat-topped white aster, cornel-leaf whitetop	N		HP		HIST			
Eclipta prostrata	yerba-de-tajo, false daisy	N		HA		HIST			
Erechtites hieraciifolius	fireweed, pilewort, American burnweed	N		HA			F, N	17.61%	0.873%
Erigeron annuus	eastern daisy fleabane	N		HA HB		HIST	F	11.36%	0.817%
Erigeron philadelphicus	daisy fleabane, Philadelphia fleabane	N		HP		HIST			
Erigeron pulchellus	robin's-plantain	N		HB HP		HIST			
Erigeron strigosus var. strigosus	daisy fleabane, prairie fleabane, whitetop	N		HA HB			F		
Eupatorium perfoliatum	boneset, common boneset	N		HP		HIST	F		
Eupatorium serotinum	late eupatorium, late-flowering thoroughwort	I		HP			F		
Eupatorium sessilifolium	upland boneset, upland eupatorium	N		HP		HIST			
Euthamia graminifolia	grassleaf goldenrod, flat-topped goldenrod	N		HP		HIST	F, P	2.84%	0.111%
Eutrochium fistulosum	joe-pye-weed, hollow-stemmed joe-pye-weed, trumpetweed	N		HP		HIST			
Eutrochium purpureum	joe-pye-weed, sweet-scented joe-pye-weed	N		HP		HIST			
Gnaphalium uliginosum	low cudweed	N		HA		HIST			
Helenium autumnale	common sneezeweed	N		HP		HIST	F		
Helenium flexuosum	southern sneezeweed	I		HP			F		

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Helianthus decapetalus	thinleaf sunflower	N		HP		HIST			
Helianthus divaricatus	rough sunflower, woodland sunflower	N		HP		HIST			
Helianthus strumosus	roughleaf sunflower	N		HP		HIST			
Heliopsis helianthoides	ox-eye, smooth ox-eye	N		HP		HIST			
Hieracium caespitosum	king-devil, meadow hawkweed	I		HP			F	1.14%	0.006%
Hieracium flagellare	hawkweed, large mouse-ear hawkweed	I		HP		HIST	F	0.57%	0.003%
Hieracium paniculatum	Allegheny hawkweed	N		HP		HIST			
Hieracium pilosella	mouse-ear hawkweed	I		HP			F	0.57%	0.003%
Krigia biflora	dwarf dandelion, two-flowered dwarf dandelion	N		HP			F, N		
Lactuca biennis	tall blue lettuce, blue lettuce	N		HA HB		HIST			
Lactuca canadensis	wild lettuce, Canada lettuce	N		HA HB		HIST			
Lactuca saligna	willow-leaf lettuce	I		HA HB			F		
Leucanthemum vulgare	ox-eye daisy	I		HP		HIST	F, N, H	3.98%	0.014%
Matricaria discoidea	pineapple-weed, disc mayweed	I		HA			F		
Packera aurea	golden ragwort	N		HP		HIST	N		
Prenanthes serpentaria	lion's-foot, cankerweed	N	PT	HP		HIST			
Prenanthes trifoliolata	gall-of-the-earth	N		HP		HIST			
Pseudognaphalium obtusifolium	fragrant cudweed, rabbit-tobacco	N		HA HB		HIST	F	4.55%	0.084%
Rudbeckia hirta var. *pulcherrima*	black-eyed-susan	N		HB HP		HIST	F, P	2.27%	0.023%
Rudbeckia laciniata var. *laciniata*	cutleaf coneflower	N		HP		HIST			
Senecio vulgaris	common groundsel, old-man-in-the-spring	I		HA			F, N		

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Sericocarpus asteroides	white-topped aster, toothed white-topped aster	N		HP		HIST			
Solidago altissima	late goldenrod, Canada goldenrod	N		HP		HIST	F	5.68%	0.531%
Solidago arguta var. *arguta*	forest goldenrod, Harris's goldenrod	N		HP		HIST			
Solidago bicolor	silver-rod, white goldenrod	N		HP		HIST			
Solidago canadensis var. *hargeri*	Canada goldenrod, Harger's goldenrod	N		HP		HIST			
Solidago gigantea var. *gigantea*	smooth goldenrod, giant goldenrod	N		HP		HIST	F	1.14%	0.006%
Solidago hispida	hairy goldenrod	N		HP			F		
Solidago juncea	early goldenrod	N		HP			F	0.57%	0.003%
Solidago odora ssp. *odora*	sweet goldenrod, anise-scented goldenrod	N		HP		HIST	F	1.14%	0.123%
Solidago puberula	downy goldenrod	N		HP		HIST			
Solidago rugosa ssp. *rugosa* var. *rugosa*	wrinkle-leaf goldenrod	N		HP		HIST	F, P	2.84%	0.394%
Solidago squarrosa	ragged goldenrod, stout goldenrod	N		HP		HIST			
Solidago ulmifolia var. *ulmifolia*	elm-leaf goldenrod	N		HP		HIST			
Symphyotrichum cordifolium	blue wood aster, common blue wood aster	N		HP		HIST			
Symphyotrichum dumosum	bushy aster, rice button aster	N	TU	HP		HIST			
Symphyotrichum laeve var. *laeve*	smooth blue aster	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Symphyotrichum lanceolatum ssp. *lanceolatum* var. *lanceolatum*	panicled aster, white panicle aster	N		HP		HIST	P, N		
Symphyotrichum lateriflorum	calico aster	N		HP		HIST	F	2.84%	0.023%
Symphyotrichum novae-angliae	New England aster	N		HP		HIST	F, P		
Symphyotrichum patens	late purple aster, clasping aster	N		HP		HIST			
Symphyotrichum pilosum var. *pilosum*	heath aster, Pringle's aster	N		HP		HIST	F	7.39%	0.390%
Symphyotrichum puniceum	purple-stemmed aster	N		HP		HIST	N		
Symphyotrichum undulatum	clasping heartleaf aster	N		HP		HIST			
Taraxacum officinale	common dandelion	I		HP			F, P, N	17.05%	0.113%
Tragopogon dubius	yellow goatsbeard, yellow salsify	I		HB			N		
Tragopogon pratensis	meadow salsify, jack-go-to-bed-at-noon	I		HB			F		
Vernonia glauca	Appalachian ironweed, tawny ironweed, broadleaf ironweed	N	PE	HP		HIST	D		
Vernonia noveboracensis	New York ironweed	N		HP		HIST	N		
BIGNONIACEAE									
Catalpa speciosa	northern catalpa, cigar-tree	I		TD			F		
BORAGINACEAE									
Hackelia virginiana	beggar's-lice, stickseed	N		HB		HIST	F	0.57%	0.001%
Myosotis scorpioides	forget-me-not, water scorpiongrass	I		HP			F		
Myosotis verna	spring forget-me-not, early scorpion-grass	N		HA		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	documented historically	present-day occurrence source(s)	2007 frequency (%)	2007 mean cover (%)
CAMPANULACEAE									
Campanula aparinoides	marsh bellflower	N		HP		HIST			
Lobelia inflata	Indian-tobacco	N		HA		HIST	F	2.27%	0.009%
Lobelia spicata var. *spicata*	spiked lobelia, palespike lobelia	N		HP		HIST			
Triodanis perfoliata var. *perfoliata*	Venus's-looking-glass	N		HA		HIST	F		
CAPRIFOLIACEAE									
Lonicera dioica var. *dioica*	mountain honeysuckle, limber honeysuckle	N		SD		HIST			
Lonicera japonica	Japanese honeysuckle	II		VW		HIST	F, P, N, H	51.70%	15.997%
Lonicera maackii	Amur honeysuckle	II		SD			F		
Lonicera morrowii	Morrow's honeysuckle	II		SD			F, N	1.14%	0.003%
Lonicera sempervirens	trumpet honeysuckle	N		VW		HIST			
Symphoricarpos orbiculatus	coralberry, Indian-currant	N		SD		HIST			
Triosteum perfoliatum	horse-gentian, feverwort	N		HP		HIST			
CONVOLVULACEAE									
Calystegia sepium	hedge bindweed, wild morning-glory, hedge false bindweed	N		VP			F, P	0.57%	0.003%
Convolvulus arvensis	field bindweed	II		VP		HIST	F	5.11%	0.044%
Cuscuta campestris	five-angled dodder	N	PT	VA		HIST			
Cuscuta gronovii var. *gronovii*	common dodder, scaldweed	N		VA		HIST			
Ipomoea pandurata	man-of-the-earth, wild potato-vine	N		VP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
LAMIACEAE									
Agastache nepetoides	yellow giant-hyssop	N		HP		HIST			
Clinopodium vulgare	wild basil	I		HP		HIST	F, P, N, H	11.93%	0.941%
Cunila origanoides	common dittany, stone-mint	N		HP		HIST			
Glechoma hederacea	gill-over-the-ground, ground-ivy	I		HP		HIST	F, H	3.98%	0.177%
Hedeoma pulegioides	American pennyroyal, American false pennyroyal, pudding-grass	N		HA		HIST			
Lycopus americanus	American water horehound	N		HP			F	0.57%	0.001%
Lycopus uniflorus	northern bugleweed, water-horehound	N		HP		HIST	F	0.57%	0.001%
Mentha arvensis	field mint, wild mint	N		HP		HIST	F		
Mentha spicata	spearmint	I		HP		HIST	F	0.57%	0.003%
Monarda fistulosa	horsemint, wild bergamot	N		HP			F		
Origanum vulgare	oregano	I		HP			F		
Prunella vulgaris ssp. *lanceolata*	heal-all, self-heal	N		HP		HIST	F, P	1.70%	0.006%
Pycnanthemum clinopodioides	basil mountain-mint	N	PX	HP		HIST			
Pycnanthemum incanum	hoary mountain-mint	N		HP		HIST			
Pycnanthemum muticum	clustered mountain-mint	N		HP			F		
Pycnanthemum tenuifolium	narrowleaf mountain-mint, slender mountain-mint	N		HP			F	1.70%	0.340%
Pycnanthemum virginianum	Virginia mountain-mint	N		HP			F, N	3.41%	0.307%
Salvia lyrata	lyre-leaf sage	N		HP			F	1.14%	0.006%
Scutellaria elliptica var. *elliptica*	hairy skullcap	N		HP		HIST			
Scutellaria integrifolia	hyssop skullcap, helmet-flower	N		HP		HIST			

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Scutellaria lateriflora	mad-dog skullcap, blue skullcap	N		HP		HIST			
Stachys tenuifolia	creeping hedge-nettle, smooth hedge-nettle	N		HP		HIST			
Teucrium canadense var. *virginicum*	wild germander, wood-sage	N		HP			F, N	1.14%	0.003%
Trichostema dichotomum	blue-curls, forked blue-curls	N		HA		HIST	F, P	0.57%	0.003%
OLEACEAE									
Fraxinus americana var. *americana*	white ash	N		TD		HIST	N		
Fraxinus pennsylvanica	green ash, red ash	N		TD		HIST			
OROBANCHACEAE									
Agalinis tenuifolia	slender false foxglove	N		HA		HIST			
Aureolaria pedicularia	cutleaf false foxglove, fernleaf yellow false foxglove	N		HA		HIST			
Melampyrum lineare var. *americanum*	cow-wheat, narrowleaf cow-wheat	N		HA		HIST			
PHRYMACEAE									
Mimulus ringens	Allegheny monkey-flower	N		HP		HIST			
PLANTAGINACEAE									
Gratiola neglecta	hedge-hyssop, mud-hyssop, clammy mud-hyssop	N		HA		HIST			
Linaria canadensis	old-field toadflax, Canada toadflax	N	SP	HA		HIST			
Linaria vulgaris	butter-and-eggs	I		HP		HIST	F, P, N, H	38.07%	2.161%
Lindernia dubia var. *anagallidea*	yellow-seeded false pimpernel	N		HA		HIST			
Penstemon digitalis	tall white beard-tongue, talus-slope penstemon	N		HP		HIST	F, P, N	0.57%	0.003%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
Penstemon hirsutus	northeastern beard-tongue, hairy beard-tongue	N		HP		HIST	F		
Plantago aristata	bristly plantain, buckhorn, large-bracted plantain	I		HA			F		
Plantago lanceolata	English plantain, narrowleaf plantain, ribgrass	I		HP HA			F, P, N, H	48.86%	0.599%
Plantago major	broadleaf plantain, common plantain, white-man's-foot	I		HP		HIST	F	0.57%	0.001%
Plantago rugelii	Rugel's plantain, broadleaf plantain, black-seeded plantain	N		HP		HIST	N		
Plantago virginica	dwarf plantain, pale-seeded plantain, Virginia plantain	N		HA HB		HIST	F		
Veronica americana	American speedwell, American brooklime	N		HP		HIST			
Veronica arvensis	corn speedwell	I		HA		HIST	F, N	14.77%	0.099%
Veronica officinalis	common speedwell, gypsyweed	N		HP		HIST			
Veronica peregrina ssp. *peregrina*	neckweed, hairy purslane speedwell	N		HA		HIST			
Veronica scutellata	marsh speedwell, narrowleaf speedwell, skullcap speedwell	N		HP		HIST			
RUBIACEAE									
Diodia teres	rough buttonweed, poor-joe	N		HA		HIST	F		
Galium aparine	bedstraw, cleavers, goosegrass, stickywilly	N		HA		HIST	F	0.57%	0.001%
Galium mollugo	white bedstraw, wild madder, false baby's-breath	I		HP		HIST	F	5.11%	0.043%
Galium triflorum	sweet-scented bedstraw, fragrant bedstraw	N		HP		HIST			
Houstonia caerulea	bluets, Quaker-ladies, azure bluet	N		HP			F	0.57%	0.109%

taxon	common name(s)	origin	state status	growth form	C_3 or C_4	document-ed histor-ically	present-day occurrence source(s)	2007 frequen-cy (%)	2007 mean cover (%)
SCROPHULARIACEAE									
Scrophularia marilandica	eastern figwort, carpenter's-square	N		HP		HIST	F		
Verbascum blattaria	moth mullein	I		HB		HIST	F	1.14%	0.003%
Verbascum thapsus	common mullein, flannel-plant	I		HB		HIST	F	5.11%	0.164%
SOLANACEAE									
Physalis heterophylla	clammy ground-cherry	N		HP		HIST			
Physalis subglabrata	longleaf ground-cherry	N		HP		HIST	F		
Solanum carolinense	horse-nettle, Carolina horse-nettle	N		HP		HIST	F, P	48.30%	0.951%
VALERIANACEAE									
Valerianella umbilicata	corn-salad, navel corn-salad	N		HA		HIST			
VERBENACEAE									
Verbena hastata	blue vervain, simpler's-joy, swamp verbena	N		HP		HIST	F		
Verbena urticifolia var. *urticifolia*	white vervain	N		HA HP		HIST	F	0.57%	0.001%

Index to Plants in Appendix C

Appendix D. Traits of Plants Suggested for Use in Grassland and Meadow Reclamation in Valley Forge National Historical Park

Appendix D. Traits of Plants Suggested for Use in Grassland and Meadow Reclamation in Valley Forge National Historical Park

The 527 native plants on the list (nomenclature from Rhoads and Block 2007) are grassland/meadow specialists (see pp. 22-23 in *Methods*). Species of special conservation concern are omitted here but comprise Appendix E (p. 239). Plants are grouped into nine categories:

- 30 **perennial cool-season grasses** (p. 209)
- 17 **perennial warm-season grasses** (p. 210)
- 10 **annual grasses**—(p. 212)
- 238 **perennial forbs** (p. 212)
- 90 **annual, biennial and other short-lived forbs** (p. 225)
- 57 **perennial rushes and sedges** (p. 230)
- 6 **annual sedges** (p. 233)
- 13 **non-flowering herbaceous perennials** (p. 233)
- 66 **shrubs, small trees, woody vines** (p. 234)

Woody species are suggested for limited uses where short-statured trees, shrubs or woody vines are appropriate, e.g., hedgerows, visual screens for parking lots and other facilities, and recreated savannas.

Wetland status, maximum height and environmental stress tolerances (sources: Rhoads and Block 2007; Fernald 1950; Gleason and Cronquist 1967) will help in matching species to site conditions and selecting species to plant together. For instance, survival is likely to be higher in mixtures where height does not vary widely, because most of the species on the list have low shade tolerance.

More than 25% of the 740 species in Appendices D and E are available commercially from nearby native plant suppliers and more native grassland species are becoming available each year. However, only plants reared from seed of remnant, unplanted, native populations in the Greater Piedmont are appropriate for use in grassland and meadow reclamation in VAFO.

If seeds of genotypes indigenous to the region are not presently available for a desired species, the best option is custom seed production, using seeds collected in small quantities from remnant native populations to establish production plots. The seed output can then be used to populate larger reclamation areas. Suppliers are increasingly accommodating to restorationists' concerns about provenance and genotype and may undertake custom seed production if the desired quantity and price make the effort worthwhile. Alternatively, consideration may be given to VAFO staff and volunteers collecting seed and establishing production plots within the park. It is vital that care is taken to verify that seed sources are of locally indigenous stock and that caution is used to prevent overcollecting that might endanger the ecosystem integrity and long-term viability of the sources.

Wetland status (blank = unrated):

OBL	obligate wetland species
FACW	mainly wet or mesic habitats
FAC	mainly mesic habitats
FACU	mainly mesic or upland habitats
UPL	mainly upland habitats
+	wetter
–	drier

Maximum height categories:

		cm range
very tall	9 to 10 or more feet	≥ 260
tall	6 to 8 feet	170–250
intermediate	3½ to 5 feet	100–160
short	1½ to 3 feet	50–90
very short or prostrate	less than 1½ feet	< 50

Valley Forge status:

HIST	documented historically at or near Valley Forge
PRES	confirmed present 1991–2007

Frequency among 99 historical reference sites:

range 3–50 (see *Results*, pp. 32-33, for explanation)

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
PERENNIAL COOL-SEASON GRASSES						
Agrostis hyemalis	ticklegrass, spring bentgrass	FAC	short	dry		18
Agrostis perennans	autumn bentgrass, upland bentgrass	FACU	intermediate	dry	HIST PRES	28
Agrostis scabra	fly-away grass, ticklegrass, rough bentgrass	FAC	short	sandy		9
Calamagrostis canadensis var. *canadensis*	Canada bluejoint	FACW+	tall	wet		12
Calamagrostis canadensis var. *macouniana*	Canada bluejoint	FACW+	tall	wet		
Danthonia compressa	northern oatgrass	FACU–	short	dry	HIST	11
Danthonia spicata	poverty grass, poverty oatgrass		short	dry, sandy	HIST PRES	
Deschampsia flexuosa	wavy hairgrass, common hairgrass		intermediate	dry	HIST	
Dichanthelium acuminatum	tapered rosette grass	FAC	intermediate	dry	HIST PRES	46
Dichanthelium boscii	Bosc's panic-grass		short	riparian	HIST	23
Dichanthelium clandestinum	deer-tongue, deer-tongue grass	FAC+	tall	sandy	PRES	33
Dichanthelium columbianum	hemlock rosette grass		short	dry, sandy		7
Dichanthelium commutatum ssp. *ashei*	variable panic-grass		short	dry		
Dichanthelium commutatum ssp. *commutatum*	oval-leaf panic-grass	FACU+	short	dry	HIST	18
Dichanthelium depauperatum	poverty panic-grass		very short or prostrate	dry	HIST	23
Dichanthelium latifolium	broadleaf rosette grass	FACU–	intermediate	riparian		23
Dichanthelium linearifolium	slimleaf witchgrass		short	dry	HIST	26

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Dichanthelium sphaerocarpon	round-fruited panic-grass, round-seeded panic-grass	FACU	short	dry		23
Elymus canadensis var. *canadensis*	Canada wild-rye	FACU+	intermediate	riparian	HIST	7
Elymus riparius	riverbank wild-rye	FACW	tall	riparian	HIST PRES	29
Elymus virginicus	Virginia wild-rye	FACW–	tall	riparian	HIST PRES	28
Festuca obtusa	nodding fescue	FACU	intermediate		HIST	24
Hordeum jubatum	foxtail-barley	FAC	short	dry		6
Leersia oryzoides	rice cutgrass	OBL	tall	wet	HIST PRES	20
*Phalaris arundinacea**	reed canary-grass*	FACW	tall	riparian	PRES	23
Poa palustris	fowl bluegrass	FACW	tall	wet, riparian		8
Sphenopholis nitida	shining wedgegrass, shiny wedgescale		short	dry	HIST	24
Sphenopholis obtusata var. *major*	slender wedgegrass	FAC–	intermediate	riparian		29
Sphenopholis obtusata var. *obtusata*	prairie wedgegrass	FAC–	intermediate	dry		
Sphenopholis pensylvanica	swamp-oats	OBL	short	wet		15
PERENNIAL WARM-SEASON GRASSES						
Andropogon gerardii	big bluestem, turkeyfoot	FAC–	very tall	riparian	HIST PRES	23
Andropogon virginicus	broom-sedge	FACU	tall	dry	HIST PRES	25

* *Phalaris arundinacea* is native to North America and Eurasia. Most wild plants here are thought to be descended from Eurasian stock planted as forage. Some Eurasian genotypes are aggressively invasive and cannot be reliably distinguished from native genotypes. It should be treated as a nonnative invasive species.

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Digitaria cognata	fall witchgrass		short	sandy	HIST PRES	6
Eragrostis spectabilis	purple lovegrass, tumblegrass	UPL	short	dry, sandy	HIST PRES	26
Muhlenbergia frondosa	wirestem muhly	FAC	intermediate	riparian	HIST PRES	33
Muhlenbergia mexicana	Mexican muhly satingrass	FACW	intermediate	riparian		17
Panicum anceps	beaked panic-grass	FAC	intermediate	sandy	HIST PRES	32
Panicum rigidulum	red-top panic-grass	FACW+	very short or prostrate	sandy	PRES	24
Panicum stipitatum	tall flat panic-grass	FACW+	intermediate	wet, sandy, riparian		9
Panicum virgatum	switchgrass	FAC	tall	sandy, riparian	HIST PRES	23
Paspalum laeve	field beadgrass	FAC+	short	sandy	PRES	21
Schizachyrium scoparium var. *scoparium*	little bluestem	FACU	intermediate		HIST PRES	14
Setaria parviflora	perennial foxtail	FAC	intermediate	dry	PRES	20
Sorghastrum nutans	Indian-grass	UPL	tall	dry	HIST PRES	31
Spartina pectinata	prairie cordgrass, freshwater cordgrass	OBL	tall	wet, sandy, riparian		10
Sporobolus cryptandrus	sand dropseed	UPL	intermediate	dry, sandy, riparian		
Tridens flavus	purpletop	FACU	tall		HIST PRES	28

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
ANNUAL GRASSES (all are warm-season except *Alopecurus carolinianus*)						
Alopecurus carolinianus	Carolina foxtail, tufted foxtail	FACW	short			
Aristida oligantha	prairie three-awn		very short or prostrate	dry	HIST PRES	12
Echinochloa muricata	rough barnyard-grass, cockspur	FACW+	tall	riparian	HIST PRES	20
Eragrostis capillaris	lacegrass		short	dry, sandy	HIST	25
Leptochloa fascicularis	sprangletop	FACW	short			
Panicum capillare	witchgrass	FAC–	short	riparian	PRES	31
Panicum dichotomiflorum	smooth panic-grass	FACW–	intermediate	dry	HIST PRES	33
Panicum gattingeri	Gattinger's panic-grass	FAC	intermediate	sandy		50
Panicum philadelphicum	Philadelphia panic-grass	FAC–	short	dry	HIST	17
Sporobolus vaginiflorus	poverty grass, poverty dropseed	UPL	short	dry, sandy	PRES	28
PERENNIAL FORBS						
Agastache nepetoides	yellow giant-hyssop	FACU	tall		HIST	23
Agastache scrophulariifolia	purple giant-hyssop		tall			13
Ageratina altissima var. *altissima*	common white snakeroot		tall		HIST PRES	23
Agrimonia gryposepala	tall hairy agrimony, harvest-lice	FACU	tall		HIST	19
Agrimonia rostellata	woodland agrimony	FACU	intermediate		HIST	7
Agrimonia striata	roadside agrimony	FACU–	intermediate	riparian	HIST	7
Allium cernuum	nodding onion		short	dry, riparian		4
Anaphalis margaritacea	pearly everlasting		short	dry, sandy	HIST	21
Angelica atropurpurea	purple-stemmed angelica	OBL	tall	wet, riparian		6
Angelica venenosa	deadly angelica, hairy angelica		tall	dry		18

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Antennaria howellii	Howell's pussytoe		very short or prostrate	dry	HIST	19
Antennaria neglecta	overlooked pussytoe	UPL	very short or prostrate		HIST PRES	25
Antennaria parlinii	Parlin's pussytoe		short	dry, shaly	HIST PRES	35
Antennaria plantaginifolia	plantain-leaf pussytoe		very short or prostrate	shaly	HIST PRES	24
Apocynum androsaemifolium	pink dogbane, spreading dogbane		short	dry	HIST	29
Apocynum cannabinum	Indian-hemp	FACU	tall	sandy	HIST PRES	46
Aralia hispida	bristly sarsaparilla		intermediate	dry		6
Arnoglossum atriplicifolium	pale Indian-plantain		very tall			15
Asclepias amplexicaulis	bluntleaf milkweed		short	dry, sandy		12
Asclepias exaltata	poke milkweed, tall milkweed	FACU	tall			16
Asclepias incarnata ssp. *incarnata*	swamp milkweed	OBL	tall	wet	PRES	14
Asclepias quadrifolia	fourleaf milkweed		short	dry		30
Asclepias syriaca	common milkweed	FACU–	tall		HIST PRES	29
Asclepias tuberosa	butterfly-weed		short	dry, shaly	PRES	29
Asclepias verticillata	whorled milkweed		short	calcareous, dry, sandy, shaly		6
Asclepias viridiflora	green milkweed		short	dry	HIST PRES	22
Baptisia tinctoria	wild indigo		intermediate	dry, sandy	HIST	19
Brickellia eupatorioides	false boneset		tall	dry, shaly	HIST	10
Calopogon tuberosus	grass-pink	FACW+	short	wet		10

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Caltha palustris	marsh-marigold	OBL	very short or prostrate	calcareous, wet		21
Campanula aparinoides	marsh bellflower	OBL	short	wet, riparian	HIST	28
Cerastium arvense ssp. *arvense*	field chickweed		very short or prostrate	dry, sandy	PRES	16
Chamaelirium luteum	devil's-bit, fairy-wand	FAC	intermediate		HIST	22
Chimaphila umbellata	pipsissewa, prince's-pine		very short or prostrate	dry		18
Cicuta bulbifera	water-hemlock	OBL	intermediate	wet		12
Cicuta maculata var. *maculata*	beaver-poison, musquash-root, spotted cowbane	OBL	tall	wet, riparian	HIST	15
Claytonia virginica	spring-beauty	FAC	very short or prostrate	riparian	HIST	32
Coreopsis tripteris	tall tickseed	FAC	very tall			4
Cunila origanoides	common dittany, stone-mint		very short or prostrate	dry, shaly	HIST	24
Desmodium canescens	hoary tick-trefoil		very short or prostrate	dry	HIST	18
Desmodium marilandicum	Maryland tick-clover		intermediate	dry	PRES	22
Desmodium paniculatum	panicled tick-trefoil	UPL	intermediate	dry	HIST	30
Doellingeria infirma	flat-topped white aster		intermediate		HIST	9
Epilobium angustifolium	fireweed	FAC	very tall	sandy		11
Epilobium leptophyllum	willow-herb	OBL	intermediate	wet		6
Erigeron philadelphicus	daisy fleabane	FACU	intermediate		HIST	30
Erythronium americanum	yellow trout-lily		very short or prostrate		HIST	29
Eupatorium altissimum	tall eupatorium, tall thoroughwort		tall	dry		8

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Eupatorium hyssopifolium	hyssop-leaf eupatorium, hyssop-leaf thoroughwort		intermediate	dry, sandy, riparian		10
Eupatorium perfoliatum	common boneset	FACW+	tall	wet, riparian	HIST PRES	30
Eupatorium sessilifolium	upland eupatorium, upland boneset		tall	dry	HIST	17
Euphorbia corollata	flowering spurge		intermediate	dry, sandy, shaly		23
Euthamia graminifolia	grassleaf goldenrod, flat-topped goldenrod	FAC	tall	riparian	HIST PRES	32
Eutrochium fistulosum	joe-pye-weed, hollow-stemmed joe-pye-weed, trumpetweed	FACW	very tall		HIST	27
Eutrochium purpureum	joe-pye-weed, sweet-scented joe-pye-weed		tall		HIST	22
Fragaria virginiana	wild strawberry	FACU	very short or prostrate	dry	HIST PRES	37
Galium boreale	northern bedstraw	FACU	short			17
Galium pilosum	hairy bedstraw, cleavers		intermediate	dry, sandy, shaly		22
Galium triflorum	sweet-scented bedstraw	FACU	short		HIST	27
Gentiana andrewsii	bottle gentian, prairie closed gentian	FACW	intermediate			24
Gentiana clausa	meadow closed gentian, bottle gentian	FACW	intermediate	riparian		11
Geranium maculatum	wood geranium	FACU	short		HIST	36
Geum canadense	white avens	FACU	intermediate	riparian	HIST	28
Geum laciniatum	herb-bennet, rough avens	FAC+	intermediate	wet		10
Hasteola suaveolens	sweet-scented Indian-plantain		tall	shaly, riparian		3
Helenium autumnale	common sneezeweed	FACW+	tall	wet, riparian	HIST PRES	19

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Helianthemum canadense	frostweed, long-branch frostweed		very short or prostrate	dry, sandy		16
Helianthus decapetalus	thinleaf sunflower	FACU	tall	riparian	HIST	26
Helianthus divaricatus	rough sunflower, woodland sunflower		tall	dry, shaly	HIST	18
Helianthus giganteus	swamp sunflower	FACW	very tall	wet		19
Helianthus strumosus	roughleaf sunflower		tall	riparian	HIST	18
Heliopsis helianthoides	ox-eye, smooth ox-eye		tall	riparian	HIST	25
Heracleum lanatum	cow-parsnip	FACU–	very tall	riparian	HIST	12
Heuchera pubescens	downy alum-root		short	shaly		5
Hieracium scabrum	rough hawkweed		tall	dry		22
Houstonia caerulea	bluets, Quaker-ladies	FACU	very short or prostrate		PRES	22
Houstonia longifolia	longleaf bluets		short	dry, sandy, shaly		8
Hydrocotyle americana	marsh pennywort, navelwort	OBL	very short or prostrate	wet	HIST	20
Hydrocotyle ranunculoides	floating pennywort	OBL	very short or prostrate	wet, riparian		7
Hypericum mutilum	dwarf St. John's-wort	FACW	short	riparian	HIST PRES	33
Hypericum punctatum	spotted St. John's-wort	FAC–	intermediate		HIST PRES	35
Hypericum pyramidatum	great St. John's-wort	FAC	tall	riparian		9
Hypoxis hirsuta	yellow star-grass	FAC	very short or prostrate	dry	HIST	35
Ipomoea pandurata	man-of-the-earth, wild potato-vine	FACU	very tall	calcareous	HIST	29
Krigia biflora	two-flowered dwarf dandelion, two-flowered cynthia	FACW	short	sandy	PRES	24

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Lechea intermedia	large-pod pinweed		short	dry, sandy		
Lechea pulchella	Leggett's pinweed		short	dry, sandy		25
Lechea racemulosa	Illinois pinweed		very short or prostrate	dry, shaly		12
Lespedeza capitata	round-headed bush-clover, round-headed lespedeza	FACU–	tall	dry	HIST	13
Lespedeza hirta	hairy bush-clover, hairy lespedeza		intermediate	dry		22
Lespedeza procumbens	trailing bush-clover, trailing lespedeza		intermediate	dry, sandy	HIST	21
Lespedeza violacea	violet bush-clover, violet lespedeza		short	dry	HIST	17
Lespedeza virginica	slender bush-clover, slender lespedeza		intermediate	dry	HIST PRES	22
Liatris spicata var. *spicata*	dense blazing-star	FAC+	tall			9
Lilium canadense ssp. *canadense*	Canada lily	FAC+	tall	wet	HIST	17
Lilium philadelphicum	wood lily	FACU+	intermediate	dry		15
Lilium superbum	Turk's-cap lily	FACW+	tall	sandy		14
Linum medium var. *texanum*	yellow flax	FACU	intermediate	dry, sandy		7
Linum virginianum	slender yellow flax	FACU	short	dry, shaly		19
Liparis loeselii	yellow twayblade	FACW	very short or prostrate	calcareous, wet		11
Lobelia cardinalis	cardinal-flower	FACW+	tall	wet, riparian		27
Lobelia siphilitica	great blue lobelia	FACW+	tall	riparian		36
Lobelia spicata var. *scaposa*	spiked lobelia	FAC–	intermediate	shaly		
Lobelia spicata var. *spicata*	spiked lobelia	FAC–	intermediate	dry	HIST	16
Ludwigia alternifolia	seedbox, false loosestrife	FACW+	intermediate	wet	HIST	29
Ludwigia palustris	marsh-purslane, marsh seedbox, water-purslane	OBL	very short or prostrate	wet, riparian		31

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Lycopus americanus	water-horehound	OBL	short	wet	PRES	34
Lycopus uniflorus	bugleweed, water-horehound	OBL	short	wet	HIST PRES	27
Lysimachia ciliata	fringed loosestrife	FACW	tall	riparian	HIST	32
Lysimachia lanceolata	lanceleaf loosestrife	FAC	short	sandy, riparian		
Mentha arvensis	field mint	FACW	intermediate	wet	HIST PRES	46
Mimulus alatus	winged monkey-flower	OBL	tall	wet, riparian		17
Mimulus ringens	Allegheny monkey-flower	OBL	tall	wet, riparian	HIST	36
Moehringia lateriflora	bluntleaf sandwort	FAC	very short or prostrate	wet		6
Monarda clinopodia	white bergamot, basil bee-balm		intermediate			24
Monarda fistulosa	horsemint, wild bergamot	UPL	intermediate		PRES	21
Myosotis laxa	wild forget-me-not	OBL	very short or prostrate	wet		30
Oenothera fruticosa ssp. *fruticosa*	sundrops, narrowleaf evening-primrose	FAC	short	riparian		6
Oenothera fruticosa ssp. *glauca*	sundrops, narrowleaf evening-primrose	FAC	short	dry	HIST	10
Oenothera perennis	small sundrops, little evening-primrose	FAC–	short	dry, shaly	PRES	26
Oenothera pilosella	sundrops, meadow evening-primrose	FAC	short		HIST	
Osmorhiza claytonii	sweet-cicely	FACU–	short	wet, riparian		12
Oxalis dillenii ssp. *filipes*	southern yellow wood-sorrel		very short or prostrate		HIST	26
Oxalis stricta	common yellow wood-sorrel	UPL	short		PRES	43

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Packera aurea	golden ragwort	FACW	short		HIST PRES	37
Packera paupercula	balsam ragwort	FAC	short	riparian		27
Penstemon digitalis	tall white beard-tongue	FAC	tall		HIST PRES	22
Penstemon hirsutus	northeastern beard-tongue		short	dry	HIST PRES	24
Persicaria hydropiperoides	mild water-pepper, water-smartweed	OBL	intermediate	wet, riparian	PRES	19
Persicaria virginiana	jumpseed	FAC	tall			28
Phlox maculata	wild sweet-william	FACW	short	wet		26
Phlox subulata ssp. *subulata*	moss-pink, creeping phlox		very short or prostrate	dry		14
Physalis heterophylla	clammy ground-cherry		short	sandy	HIST	38
Physalis subglabrata	longleaf ground-cherry		short		HIST PRES	28
Physostegia virginiana	false dragonhead	FAC+	intermediate	riparian		10
Phytolacca americana	pokeweed	FACU+	very tall		PRES	33
Plantago rugelii	Rugel’s plantain, broadleaf plantain	FACU	very short or prostrate	wet	HIST PRES	23
Platanthera grandiflora	large purple fringed-orchid	FACW	tall			5
Platanthera lacera	ragged fringed-orchid	FACW	short		HIST PRES	18
Pogonia ophioglossoides	rose pogonia	OBL	very short or prostrate	wet		15
Polygonatum biflorum var. *biflorum*	smooth Solomon’s-seal	FACU	tall		HIST	21
Polygonatum biflorum var. *commutatum*	smooth Solomon’s-seal	FACU	tall	riparian		12

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Polygonatum pubescens	hairy Solomon's-seal		intermediate	riparian	HIST	23
Potentilla canadensis	dwarf cinquefoil		very short or prostrate	dry	PRES	26
Potentilla simplex	old-field cinquefoil	FACU–	short	dry	HIST PRES	25
Prenanthes alba	white rattlesnake-root	FACU	tall			19
Prenanthes trifoliolata	gall-of-the-earth		intermediate	sandy, shaly	HIST	19
Prunella vulgaris ssp. *lanceolata*	heal-all, self-heal	FACU+	short		HIST PRES	19
Pycnanthemum incanum	hoary mountain-mint		intermediate		HIST	21
Pycnanthemum muticum	short-toothed mountain-mint, clustered mountain-mint	FACW	short		PRES	12
Pycnanthemum tenuifolium	narrowleaf mountain-mint, slender mountain-mint	FACW	short	sandy, riparian	PRES	27
Pycnanthemum verticillatum var. *verticillatum*	whorled ountain-mint	FAC	intermediate			8
Pycnanthemum virginianum	Virginia mountain-mint	FAC	intermediate		PRES	32
Ranunculus hispidus var. *caricetorum*	marsh buttercup, northern swamp buttercup	FAC	short	riparian		19
Rhexia virginica	meadow-beauty, handsome Harry	OBL	intermediate	wet, sandy		15
Rudbeckia fulgida var. *speciosa*	orange coneflower	FAC	intermediate			
Rudbeckia laciniata var. *laciniata*	cutleaf coneflower	FACW	very tall	wet, riparian	HIST	19
Rudbeckia triloba var. *triloba*	three-lobed coneflower	FACU	tall			14
Salvia lyrata	lyreleaf sage	UPL	short		PRES	23
Sanguinaria canadensis	bloodroot, red puccoon	UPL	very short or prostrate			28
Sanguisorba canadensis	American burnet	FACW+	tall	wet		19

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Sanicula marilandica	black snakeroot, black sanicle	UPL	tall		HIST	14
Scrophularia lanceolata	lanceleaf figwort	FACU+	tall	riparian		16
Scrophularia marilandica	eastern figwort, carpenter's-square	FACU–	very tall	riparian	HIST PRES	20
Scutellaria galericulata	common skullcap	OBL	short	wet		7
Scutellaria incana	downy skullcap		intermediate			6
Scutellaria integrifolia	hyssop skullcup	FACW	short		HIST	37
Scutellaria lateriflora	mad-dog skullcap	FACW+	short	wet, riparian	HIST	25
Senna hebecarpa	northern wild senna	FAC	tall	sandy, riparian	HIST	24
Sericocarpus asteroides	white-topped aster		short	dry	HIST	19
Silene caroliniana ssp. *pensylvanica*	Pennsylvania catchfly, sticky catchfly		very short or prostrate	dry, shaly		10
Silene stellata	starry campion		intermediate		HIST	34
Silphium asteriscus var. *trifoliatum*	whorled rosinweed		tall	dry		
Sisyrinchium angustifolium	narrowleaf blue-eyed-grass	FACW–	short		HIST PRES	28
Sisyrinchium mucronatum	needletip blue-eyed-grass	FAC+	very short or prostrate	dry	HIST PRES	26
Sium suave	water-parsnip	OBL	tall	wet		15
Solanum carolinense	horse-nettle	UPL	intermediate	sandy, riparian	HIST PRES	26
Solidago altissima	late goldenrod	FACU	tall	riparian	HIST PRES	17
Solidago arguta var. *arguta*	forest goldenrod		tall	dry	HIST	20
Solidago bicolor	silver-rod, white goldenrod		intermediate	dry, shaly	HIST	28
Solidago canadensis var. *canadensis*	Canada goldenrod	FACU	tall			

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Solidago canadensis var. *hargeri*	Canada goldenrod	FACU	tall		HIST	18
Solidago gigantea var. *gigantea*	smooth goldenrod	FACW	tall	riparian	HIST PRES	17
Solidago gigantea var. *serotina*	smooth goldenrod	FACW	tall			7
Solidago hispida	hairy goldenrod		intermediate	dry	PRES	
Solidago juncea	early goldenrod		intermediate		PRES	24
Solidago nemoralis	gray goldenrod		intermediate	dry		31
Solidago puberula	downy goldenrod	FACU–	intermediate		HIST	15
Solidago rugosa ssp. *aspera* var. *aspera*	wrinkle-leaf goldenrod	FAC	tall			13
Solidago rugosa ssp. *rugosa* var. *rugosa*	wrinkle-leaf goldenrod	FAC	tall		HIST PRES	26
Solidago rugosa ssp. *rugosa* var. *sphagnophila*	wrinkle-leaf goldenrod	FAC	tall	wet		
Solidago squarrosa	ragged goldenrod, stout goldenrod		tall		HIST	12
Solidago ulmifolia var. *ulmifolia*	elm-leaf goldenrod		tall	shaly	HIST	15
Spiranthes cernua	nodding ladies'-tresses	FACW	very short or prostrate			32
Spiranthes lacera var. *gracilis*	southern slender ladies'-tresses	FACU–	very short or prostrate	dry	HIST	16
Spiranthes lacera var. *lacera*	northern slender ladies'-tresses	FACU–	very short or prostrate			
Spiranthes ochroleuca	yellow nodding ladies'-tresses	FACW	very short or prostrate		HIST	14
Stachys tenuifolia	creeping hedge-nettle	FACW+	intermediate	wet, riparian	HIST	24
Stellaria longifolia	longleaf stitchwort	FACW	very short or prostrate			29

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Symphyotrichum laeve var. *concinnum*	smooth blue aster		intermediate	dry		
Symphyotrichum laeve var. *laeve*	smooth blue aster		intermediate	dry	HIST	18
Symphyotrichum lanceolatum ssp. *lanceolatum*	panicled aster		tall		HIST PRES	30
Symphyotrichum lowrieanum	smooth heartleaf aster		intermediate	dry, shaly		16
Symphyotrichum novae-angliae	New England aster	FAC	tall		HIST PRES	27
Symphyotrichum phlogifolium	late purple aster		tall			10
Symphyotrichum pilosum var. *pilosum*	heath aster	UPL	tall		HIST PRES	17
Symphyotrichum racemosum	small white aster	FAC	tall			15
Symphyotrichum undulatum	clasping heartleaf aster		intermediate	dry, shaly	HIST	26
Symphyotrichum urophyllum	arrowleaf aster		intermediate			11
Tephrosia virginiana	goat's-rue		short	dry, sandy	HIST	19
Teucrium canadense var. *virginicum*	wild germander, wood-sage	FACW	intermediate		PRES	21
Thalictrum pubescens	tall meadow-rue	FACW+	very tall	wet	HIST	30
Thalictrum revolutum	purple meadow-rue, skunk meadow-rue	UPL	tall	dry		14
Thaspium barbinode	meadow-parsnip	UPL	intermediate		HIST	11
Thaspium trifoliatum var. *flavum*	meadow-parsnip		short			
Tradescantia virginiana	spiderwort, widow's-tears, Virginia spiderwort	FACU	short	shaly		14
Triadenum fraseri	Marsh St. Johns-wort	OBL	short	wet		
Trichostema brachiatum	false pennyroyal		very short or prostrate	dry, shaly, riparian		7

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Triosteum perfoliatum	horse-gentian		tall	calcareous	HIST	7
Valerianella chenopodiifolia	goose-foot corn-salad		short			
Verbena hastata	blue vervain, simpler's-joy	FACW+	tall	wet	HIST PRES	28
Verbena simplex	narrowleaf vervain		short	shaly		15
Verbesina alternifolia	wingstem	FAC	tall			9
Vernonia noveboracensis	New York ironweed	FACW+	tall	wet, riparian	HIST PRES	31
Veronica officinalis	common speedwell, gypsyweed	FACU–	very short or prostrate	shaly	HIST	28
Veronicastrum virginicum	Culver's-root	FACU	tall			20
Viola cucullata	blue marsh violet	FACW+	very short or prostrate	wet	HIST	28
Viola labradorica	American dog violet	FACW	very short or prostrate	riparian	HIST	27
Viola lanceolata var. *lanceolata*	lanceleaf violet	OBL	very short or prostrate	wet, riparian		12
Viola palmata	early blue violet		very short or prostrate	dry		43
Viola pedata	birdfoot violet		very short or prostrate	dry, sandy, shaly		16
Viola primulifolia	primrose violet	FAC+	very short or prostrate			16
Viola sagittata var. *ovata*	ovateleaf violet	FACW	very short or prostrate	dry	HIST	17
Viola sagittata var. *sagittata*	arrowleaf violet	FACW	very short or prostrate	dry		20
Viola sororia	common blue violet	FAC–	very short or prostrate		PRES	40

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Waldsteinia fragarioides	barren strawberry		very short or prostrate			9
Zizia aptera	golden-alexander, meadow zizia	FAC	short			28
Zizia aurea	golden-alexander, golden zizia	FAC	short	riparian	HIST	17
ANNUAL, BIENNIAL AND OTHER SHORT-LIVED FORBS						
Acalypha gracilens	slender mercury		very short or prostrate	dry, shaly	PRES	12
Acalypha rhomboidea	common three-seeded mercury	FACU–	short		HIST PRES	30
Acalypha virginica	Virginia three-seeded mercury	FACU–	short	dry, riparian	HIST PRES	23
Agalinis purpurea	purple false-foxglove	FACW–	short	sandy, riparian		10
Agalinis tenuifolia	slender false-foxglove	FAC	short	dry	HIST	21
Ambrosia artemisiifolia	common ragweed	FACU	intermediate		HIST PRES	29
Ambrosia trifida	giant ragweed	FAC	tall			25
Arabis glabra	towercress, tower mustard		intermediate	dry		7
Arabis lyrata	lyreleaf rockcress	FACU	very short or prostrate	dry		24
Atriplex littoralis	seashore orach		intermediate			5
Aureolaria pedicularia	cut-leaf false-foxglove		intermediate	dry	HIST	22
Bartonia virginica	bartonia	FACW	very short or prostrate			19
Bidens bipinnata	spanish needles		tall	dry, shaly	HIST	27
Bidens cernua	bur-marigold, stick-tight	OBL	intermediate	wet, riparian	HIST	31
Bidens connata	beggar-ticks, stick-tight	FACW+	tall	riparian	HIST	18

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Bidens frondosa	devil's beggar-ticks, stick-tights	FACW	intermediate	riparian	HIST PRES	21
Bidens vulgata	beggar-ticks, stick-tights		intermediate	wet, riparian		6
Chamaecrista fasciculata	partridge-pea, prairie senna	FACU	short	sandy, riparian		13
Chamaecrista nictitans	wild sensitive-plant	FACU–	short	dry, sandy	HIST PRES	35
Chenopodium album var. *missouriense*	lamb's quarters		intermediate		HIST	16
Cirsium altissimum	tall thistle		very tall	riparian		7
Cirsium discolor	field thistle	UPL	tall		PRES	28
Cirsium muticum	swamp thistle	OBL	tall	wet, riparian		18
Cirsium pumilum	pasture thistle		short	dry, sandy, shaly	PRES	15
Conyza canadensis var. *canadensis*	horseweed	UPL	tall		HIST PRES	21
Crotalaria sagittalis	rattlebox		very short or prostrate	dry, sandy	HIST	23
Croton capitatus	hogwort, wooly croton		intermediate			
Cuphea viscosissima	blue waxweed, clammy cuphea	FAC–	short	dry	HIST	25
Diodia teres	rough buttonweed		short	sandy	HIST PRES	20
Eclipta prostrata	yerba-de-tajo	FAC	very short or prostrate	wet, riparian	HIST	17
Erechtites hieraciifolius	fireweed, pilewort	FACU	tall		PRES	26
Erigeron annuus	daisy fleabane	FACU	tall		HIST PRES	28
Erigeron pulchellus	robin's-plantain	FACU	very short or prostrate		HIST	20

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Erigeron strigosus var. *strigosus*	daisy fleabane, whitetop	FACU+	intermediate	dry, shaly	PRES	19
Euphorbia dentata	toothed spurge		short			6
Euphorbia nutans	eyebane	FACU–	short	dry	HIST	26
Euphorbia vermiculata	hairy spurge		very short or prostrate	dry	HIST	14
Galium aparine	stickywilly, bedstraw, cleavers, goosegrass	FACU	intermediate	riparian	HIST PRES	26
Gamochaeta purpurea var. *purpurea*	purple cudweed		very short or prostrate	dry, sandy		5
Gaura biennis	gaura, biennial bee-blossom	FACU	tall	riparian	HIST	21
Geranium carolinianum	Carolina cranesbill, Carolina geranium		short	dry	HIST PRES	28
Gnaphalium uliginosum	low cudweed	FAC	very short or prostrate	riparian	HIST	18
Gratiola neglecta	hedge hyssop, mud-hyssop	OBL	very short or prostrate	wet, riparian	HIST	27
Hackelia virginiana	beggar’s-lice, stickseed	FACU	tall	dry	HIST PRES	19
Hedeoma pulegioides	American pennyroyal, pudding-grass		very short or prostrate	dry	HIST	23
Hypericum gentianoides	orange-grass, pineweed	UPL	very short or prostrate	dry, shaly	HIST	24
Impatiens capensis	jewelweed, spotted touch-me-not	FACW	tall	riparian	HIST PRES	27
Krigia virginica	Virginia dwarf dandelion	UPL	very short or prostrate	dry, shaly		19
Lactuca biennis	tall blue lettuce	FACU	tall	riparian	HIST	15
Lactuca canadensis	wild lettuce, Canada lettuce	FACU–	tall		HIST	27

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Lactuca floridana var. *floridana*	woodland lettuce	FACU–	tall			
Lactuca floridana var. *villosa*	woodland lettuce	FACU–	tall			6
Lepidium virginicum	poor-man's-pepper, wild pepper-grass	FACU–	short	dry	PRES	38
Lindernia dubia var. *anagallidea*	yellow-seeded false pimpernel	OBL	very short or prostrate	wet, riparian	HIST	
Lobelia inflata	Indian-tobacco	FACU	intermediate		HIST PRES	31
Myosotis verna	spring forget-me-not, early scorpion-grass	FAC–	very short or prostrate	dry	HIST	16
Oenothera biennis	common evening-primrose, biennial evening-primrose	FACU–	tall		PRES	18
Oenothera laciniata	cutleaf evening-primrose	FACU–	short	dry, sandy		9
Oenothera nutans	nodding evening-primrose		tall			6
Oenothera parviflora	small-flowered evening-primrose	FACU–	short			11
Parietaria pensylvanica	pellitory		very short or prostrate	dry	HIST	24
Persicaria arifolia	halberd-leaf tearthumb	OBL	tall	wet	PRES	24
Persicaria pensylvanica	Pennsylvania smartweed, pinkweed	FACW	intermediate	riparian	HIST PRES	36
Plantago pusilla	dwarf plantain	UPL	intermediate	dry, sandy		
Plantago virginica	dwarf plantain, pale-seeded plantain	UPL	tall		HIST PRES	37
Polygala sanguinea	field milkwort, rose milkwort	FACU	very short or prostrate			30
Polygala verticillata var. *ambigua*	whorled milkwort	UPL	very short or prostrate		HIST	11
Polygala verticillata var. *isocycla*	whorled milkwort	UPL	very short or prostrate			8

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Polygala verticillata var. *verticillata*	whorled milkwort	UPL	very short or prostrate	dry		25
Polygonum erectum	erect knotweed	FACU	intermediate	riparian	HIST PRES	13
Polygonum tenue	slender knotweed		very short or prostrate	dry, shaly		30
Portulaca oleracea	purslane	FAC	very short or prostrate		HIST	11
Potentilla norvegica ssp. *monspeliensis*	strawberry-weed	FACU	short		HIST PRES	23
Pseudognaphalium obtusifolium	fragrant cudweed, rabbit-tobacco		intermediate	shaly	HIST PRES	29
Ranunculus abortivus	small-flowered crowfoot	FACW–	short	riparian		33
Rorippa palustris	marsh watercress, yellow watercress	OBL	intermediate	wet	HIST	35
Rudbeckia hirta var. *hirta*	black-eyed-susan	FACU–	intermediate			
Rudbeckia hirta var. *pulcherrima*	black-eyed-susan	FACU–	intermediate		HIST PRES	28
Sabatia angularis	common marsh-pink, rose-pink	FAC+	short	dry		31
Salvia reflexa	lanceleaf sage		short	riparian		5
Sanicula canadensis var. *grandis*	Canadian sanicle, snakeroot	UPL	tall			18
Silene antirrhina	sleepy catchfly		short	dry	HIST PRES	30
Trichostema dichotomum	blue-curls		short	dry	HIST PRES	31
Triodanis perfoliata var. *perfoliata*	Venus's looking-glass	FAC	intermediate		HIST PRES	23
Valerianella umbilicata	navel corn-salad	FAC	intermediate		HIST	23

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Verbena urticifolia var. *urticifolia*	white vervain	FACU	tall		HIST PRES	22
Veronica peregrina ssp. *peregrina*	neckweed, purslane speedwell	FACU–	very short or prostrate	riparian	HIST	24
Veronica peregrina ssp. *xalapensis*	neckweed, purslane speedwell	FACU–	very short or prostrate			
Viola bicolor	field pansy		very short or prostrate			9
Xanthium strumarium	common cocklebur	FAC	tall			35
PERENNIAL RUSHES AND SEDGES						
Luzula echinata	common woodrush	FACU	very short or prostrate	wet	HIST	19
Juncus acuminatus	sharp-fruited rush	OBL	short	wet, riparian	PRES	27
Juncus secundus	lopsided rush	FACU	short			18
Juncus tenuis var. *tenuis*	path rush	FAC–	short	dry	HIST PRES	23
Scirpus atrovirens	black bulrush	OBL	tall	wet, riparian		20
Scirpus cyperinus	wool-grass	FACW+	tall	riparian		37
Scirpus expansus	wood bulrush	OBL	tall	wet	HIST	
Scirpus georgianus	Georgia bulrush	OBL	tall	wet	HIST	20
Scirpus hattorianus	mosquito bulrush	OBL	tall	wet, riparian		14
Scirpus microcarpus	panicled bulrush	OBL	tall	wet		
Scirpus pendulus	rufous bulrush	OBL	tall	wet, sandy		14
Eleocharis erythropoda	bald spike-rush	OBL	intermediate	wet, riparian		24
Eleocharis tenuis var. *pseudoptera*	slender spike-rush	FACW+	short	wet		6
Eleocharis tenuis var. *tenuis*	slender spike-rush	FACW+	very short or prostrate	wet	PRES	18

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Cyperus esculentus	yellow nutsedge	FACW	short		HIST PRES	34
Cyperus lupulinus	Great Plains flatsedge, sand sedge	UPL	short	dry	HIST	42
Cyperus plukenetii	Plukenet's flatsedge		intermediate			
Cyperus retrofractus	rough flatsedge		short	dry		
Cyperus strigosus	false nutsedge	FACW	intermediate	riparian	HIST PRES	45
Rhynchospora capitellata	brownish beaksedge	OBL	short	wet		27
Carex aggregata	glomerate sedge	FACU	intermediate		HIST PRES	16
Carex albolutescens	green-white sedge, pale straw sedge	FACW	intermediate	wet	PRES	9
Carex amphibola	eastern narrowleaf sedge	FAC	short	dry	HIST PRES	33
Carex annectens	yellow-fruited sedge	FACW	short	dry	HIST PRES	40
Carex argyrantha	hay sedge, silvery sedge		intermediate	dry		10
Carex blanda	eastern woodland sedge	FAC	short	dry	HIST PRES	27
Carex bromoides	brome-like sedge	FACW	short	wet		14
Carex bushii	Bush's sedge	FACW	short	dry	PRES	16
Carex canescens var. *disjuncta*	silvery sedge	OBL	short	wet, riparian		5
Carex caroliniana	Carolina sedge	FACU	short	wet	HIST PRES	17
Carex cephalophora	oval-headed sedge	FACU	short	dry	HIST PRES	33
Carex communis	fibrous-root sedge, colonial oak sedge		short	dry	HIST	16
Carex conoidea	open-field sedge	FACU	short			26

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Carex cristatella	crested sedge	FACW	intermediate	wet, riparian	PRES	22
Carex glaucodea	blue sedge		short	dry	HIST PRES	30
Carex gracilescens	slender loose-flower sedge		short		PRES	16
Carex granularis var. *granularis*	limestone meadow sedge	FACW+	short	wet, riparian	PRES	13
Carex granularis var. *haleana*	limestone meadow sedge	FACW+	short	wet		
Carex grisea	eastern narrowleaf sedge, gray sedge	FAC	short	dry	PRES	13
Carex hirsutella	fuzzy wuzzy sedge		short	dry	HIST PRES	25
Carex intumescens	greater bladder sedge	FACW+	short	wet	HIST	20
Carex lucorum	Blue Ridge sedge		short	dry		6
Carex lurida	lurid sedge, shallow sedge	OBL	intermediate	wet	HIST PRES	33
Carex mesochorea	midland sedge	FACU	intermediate	dry	PRES	11
Carex muhlenbergii	Muhlenberg's sedge		intermediate	dry, sandy	HIST PRES	23
Carex normalis	greater straw sedge	FACU	tall	dry	HIST PRES	26
Carex pallescens	pale sedge		short		PRES	
Carex pellita	woolly sedge	OBL	intermediate	wet		23
Carex scoparia	broom sedge	FACW	intermediate	dry	PRES	35
Carex sparganioides	bur-reed sedge	FACU	intermediate		HIST	23
Carex stipata var. *stipata*	stalk-grain sedge, owlfruit sedge		intermediate	wet	HIST PRES	25
Carex swanii	downy green sedge, Swan's sedge	FACU	short	dry	HIST PRES	25

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Carex tribuloides var. *tribuloides*	blunt broom sedge, bristlebract sedge	FACW+	intermediate	wet		20
Carex trichocarpa	hairy-fruited sedge	OBL	intermediate	wet		15
Carex umbellata	parasol sedge		very short or prostrate	dry		20
Carex vestita	velvet sedge		intermediate	dry, sandy		16
Carex vulpinoidea	fox sedge, brown fox sedge	OBL	short	wet	HIST PRES	32
ANNUAL SEDGES						
Bulbostylis capillaris	sandrush	FACU	very short or prostrate	dry		29
Cyperus bipartitus	slender flatsedge, umbrella sedge	FACW+	very short or prostrate	wet, sandy, riparian	HIST	25
Cyperus flavescens	yellow flatsedge, umbrella sedge	OBL	very short or prostrate	wet		17
Cyperus odoratus	rusty flatsedge, umbrella sedge	FACW	short	wet, sandy	HIST	13
Cyperus tenuifolius	thinleaf flatsedge	FACW	very short or prostrate	sandy, riparian		
Fimbristylis autumnalis	slender fimbry	FACW+	very short or prostrate	wet, riparian	HIST	23
NON-FLOWERING HERBACEOUS PERENNIALS						
Selaginella apoda	meadow spikemoss	FACW	very short or prostrate	riparian	HIST	24
Lycopodium clavatum	one-cone clubmoss	FAC	very short or prostrate			9
Lycopodium dendroideum	tree ground-pine, northern tree clubmoss, prickly tree clubmoss	FACU	very short or prostrate			5

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Diphasiastrum tristachyum	deep-rooted running-pine		very short or prostrate	sandy		
Botrychium dissectum	cutleaf grape-fern	FAC	very short or prostrate		HIST PRES	39
Ophioglossum pusillum	northern adder's-tongue		very short or prostrate	dry		6
Equisetum arvense	field horsetail, devil's-guts	FAC	intermediate	riparian	HIST PRES	30
Equisetum hyemale	scouring-rush	FACW	very short or prostrate	sandy, riparian		16
Equisetum sylvaticum	woodland horsetail	FACW	short	wet		16
Dennstaedtia punctilobula	hay-scented fern		tall		HIST	25
Pteridium aquilinum	northern bracken fern	FACU	tall	sandy	HIST	21
Thelypteris palustris	marsh fern	FACW+	short	wet	HIST	17
Onoclea sensibilis	sensitive fern	FACW	intermediate	wet	HIST PRES	20
SHRUBS, SMALL TREES, AND WOODY VINES						
Amelanchier laevis	smooth serviceberry, smooth shadbush		very tall		HIST	9
Amelanchier stolonifera	low juneberry, low shadbush	FACU	tall			12
Aralia spinosa	Hercules'-club	FAC	very tall	riparian		12
Betula populifolia	gray birch	FAC	very tall	dry		22
Campsis radicans	trumpet-vine, trumpet-creeper	FAC	very tall	riparian		8
Comptonia peregrina	sweet-fern		tall	dry		13
Cornus amomum ssp. *amomum*	kinnikinik, red-willow	FACW	very tall		HIST	27
Cornus racemosa	silky dogwood	FAC–	very tall	wet	PRES	24
Cornus sericea	red-osier dogwood	FACW+	very tall			6

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Crataegus calpodendron	pear hawthorn, blackthorn hawthorn		very tall			6
Crataegus coccinea	red-fruited hawthorn		very tall	riparian	HIST	5
Crataegus crus-galli	cockspur hawthorn	FACU	very tall			18
Crataegus intricata	Biltmore hawthorn		very tall			15
Crataegus macrosperma	fanleaf hawthorn		very tall			15
Crataegus punctata	dotted hawthorn, white hawthorn		very tall	riparian	HIST	9
Crataegus succulenta	long-spined hawthorn, fleshy hawthorn		very tall		HIST	5
Diospyros virginiana	persimmon	FAC–	very tall			27
Hypericum prolificum	shrubby St. John's-wort	FACU	tall			7
Juniperus virginiana	eastern red-cedar	FACU	very tall	dry	HIST PRES	23
Lonicera sempervirens	trumpet honeysuckle	FACU	very tall		HIST	17
Malus coronaria	sweet crabapple		very tall			16
Myrica pensylvanica	bayberry	FAC	tall	dry, sandy		11
Parthenocissus inserta	grape woodbine		very tall	riparian		
Parthenocissus quinquefolia	Virginia-creeper, woodbine	FACU	very tall		HIST PRES	23
Photinia melanocarpa	black chokeberry	FAC	very tall	dry, wet		19
Physocarpus opulifolius	ninebark	FACW–	very tall	wet, sandy, riparian	HIST	23
Pinus rigida	pitch pine	FACU	very tall	dry	HIST	16
Pinus virginiana	Virginia pine		very tall	dry, sandy		24
Populus tremuloides	quaking aspen		very tall	sandy		18
Prunus americana	wild plum	FACU–	very tall	riparian	HIST	26
Prunus pensylvanica	pin cherry, fire cherry	FACU–	very tall	dry		8
Quercus ilicifolia	scrub oak, bear oak		very tall	dry, sandy		5

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Quercus marilandica	blackjack oak		very tall	dry	HIST	7
Quercus prinoides	dwarf chestnut oak		very tall	dry		14
Quercus stellata	post oak	UPL	very tall	dry	HIST	21
Rhus copallina var. *copallina*	shining sumac, winged sumac		very tall	dry		
Rhus copallina var. *latifolia*	shining sumac, dwarf sumac		very tall	shaly		14
Rhus glabra	smooth sumac		very tall	dry, shaly	HIST	25
Rhus typhina	staghorn sumac		very tall	dry		28
Rosa carolina	pasture rose	UPL	intermediate	dry, shaly	HIST	27
Rubus allegheniensis	common blackberry	FACU–	tall		PRES	15
Rubus flagellaris	prickly dewberry, northern dewberry	FACU	very tall	shaly		19
Rubus hispidus	swamp dewberry	FACW	tall		PRES	15
Rubus idaeus var. *strigosus*	red raspberry	FAC–	tall		PRES	
Rubus pensilvanicus	blackberry		very tall		PRES	16
Salix eriocephala	diamond willow	FACW+	very tall	riparian	HIST	26
Salix exigua	sandbar willow	OBL	very tall	wet, sandy, riparian		13
Salix humilis var. *humilis*	upland willow	FACU	very tall	dry, sandy		15
Salix humilis var. *tristis*	dwarf upland willow, sage willow	FACU	very tall			8
Salix nigra	black willow	FACW+	very tall	wet, riparian	HIST	29
Sambucus canadensis	American elder	FACW	very tall	riparian	HIST	29
Sassafras albidum	sassafras	FACU–	very tall		HIST PRES	31
Smilax glauca	catbrier, greenbrier	FACU	tall	dry, sandy		16
Smilax hispida	bristly greenbrier		tall			21
Smilax rotundifolia	bullbrier, greenbrier	FAC	tall	dry	HIST	24
Spiraea alba	meadow-sweet	FACW+	tall			8

taxon	common name(s)	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Spiraea latifolia	meadow-sweet	FAC+	tall			23
Spiraea tomentosa	hardhack, steeple-bush	FACW–	intermediate	wet		9
Symphoricarpos orbiculatus	coralberry, Indian-currant	UPL	tall	dry	HIST	15
Vaccinium angustifolium	low sweet blueberry	FACU–	short	dry	HIST	20
Viburnum lentago	nannyberry, sheepberry	FAC	very tall		HIST	13
Viburnum prunifolium	black-haw	FACU	very tall		HIST	31
Viburnum rafinesquianum	downy arrow-wood		very tall	dry		13
Viburnum recognitum	northern arrow-wood	FACW–	very tall	riparian		28
Vitis vulpina	frost grape	FAC	very tall	sandy		22
Zanthoxylum americanum	prickly-ash	FACU	very tall	calcareous, riparian		14

Appendix E. Plants of Special Conservation Concern Relevant to Grassland and Meadow Management in Valley Forge National Historical Park

Appendix E. Plants of Special Conservation Concern Relevant to Grassland and Meadow Management in Valley Forge National Historical Park

A few plants of special conservation concern are present in VAFO grasslands and meadows (see Table 18, pp. 49-51). It is critical that these populations are closely monitored, protected and managed to ensure their long-term viability. More rare grassland and meadow species may be found in the park as native habitat reclamation work progresses. Plants of special conservation concern also may be introduced or reintroduced as part of grassland and meadow reclamation with strict precautions (see discussion of rare species translocation, pp. 266-268), including using only genotypes from among the nearest remnant, unplanted, indigenous populations.

The list consists of grassland and meadow specialists native to the Greater Piedmont classified by the Pennsylvania Biological Survey (Pennsylvania Natural Heritage Program 2010b; S. Grund, personal communication) as species of special concern, omitting those that are mainly restricted to serpentine grasslands or represented by one or two collections in the entire region. There are 213 plants (nomenclature from Rhoads and Block 2007), arranged under the same nine categories as in Appendix D, namely:

- 8 **perennial cool-season grasses** (p. 241)
- 9 **perennial warm-season grasses** (p. 241)
- 5 **annual grasses**—all warm-season (p. 242)
- 100 **perennial forbs** (p. 242)
- 31 **annual, biennial and other short-lived forbs** (p. 247)
- 35 **perennial rushes and sedges** (p. 249)
- 3 **annual sedges** (p. 250)
- 4 **non-flowering herbaceous perennials** (p. 251)
- 18 **shrubs, small trees and woody vines** (p. 251)

See the introduction to Appendix D (p. 208) for references and notes on choosing species and acquiring seed.

Pennsylvania Biological Survey status, 2010:

PX	extirpated in the state
PE	endangered in the state
PT	threatened in the state
SP	special population deserving protection that does not fall into another category
PR	rare in the state
TU	tentatively believed to be declining or imperiled but data currently insufficient; under study

Wetland status (blank = unrated):

OBL	obligate wetland species
FACW	mainly wet or mesic habitats
FAC	mainly mesic habitats
FACU	mainly mesic or upland habitats
UPL	mainly upland habitats
+	wetter
–	drier

Maximum height categories:

		cm range
very tall	9 to 10 or more feet	≥ 260
tall	6 to 8 feet	170–250
intermediate	3½ to 5 feet	100–160
short	1½ to 3 feet	50–90
very short or prostrate	less than 1½ feet	< 50

Valley Forge status:

HIST	documented historically at or near Valley Forge
PRES	confirmed present in the park in 1991–2007

Frequency among 99 historical reference sites:

range 0–28 (see *Results*, pp. 32-33, for explanation)

(adventive?) historical or present-day occurrence in ecoregion was/is likely transitory (e.g., primarily on roadsides, rail or ship ballast)

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
PERENNIAL COOL-SEASON GRASSES							
Alopecurus aequalis	short-awned foxtail	PT	OBL	short	wet		≤ 2
Deschampsia cespitosa	tufted hairgrass	TU	FACW	intermediate	sandy		7
Dichanthelium oligosanthes	Heller's panic-grass, Scribner's panic-grass	TU	FACU	short			≤ 2
Dichanthelium scoparium	velvety panic-grass	PE	FACW	tall			7
Dichanthelium villosissimum	long-haired panic-grass	TU		short			5
Festuca paradoxa	cluster fescue	PE	FAC	tall			≤ 2
Piptochaetium avenaceum	black oatgrass	PE	UPL	intermediate	sandy		≤ 2
Tripsacum dactyloides	gammagrass, eastern gamagrass	PE	FACW	very tall	wet		≤ 2
PERENNIAL WARM-SEASON GRASSES							
Andropogon glomeratus	broom-sedge	PR	FACW+	tall	wet	HIST PRES	11
Andropogon gyrans	Elliott's beardgrass, Elliott's bluestem	PR		short		PRES	6
Aristida purpurascens	arrow-feather three-awn	PT		short	sandy		5
Bouteloua curtipendula	side-oats grama, tall grama	PT		intermediate	calcareous, sandy		3
Gymnopogon ambiguus	broadleaf beardgrass	PX		short	sandy		≤ 2
Muhlenbergia capillaris	hairgrass, short muhly	PX	FACU-	intermediate			≤ 2 (adventive?)
Muhlenbergia uniflora	fall dropseed muhly	PT	OBL	very short or prostrate	sandy, wet		≤ 2
Panicum longifolium	longleaf panic-grass	PE	OBL	intermediate	sandy, wet		7
Paspalum setaceum var. *muhlenbergii*	slender beadgrass, thin paspalum	TU	FACU+	short		PRES	23

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
ANNUAL GRASSES							
Aristida dichotoma var. *curtissii*	poverty three-awn, povertygrass	TU	UPL	short			≤ 2
Aristida longespica var. *longespica*	slender three-awn	TU	UPL	very short or prostrate	dry, sandy	HIST PRES	4
Digitaria filiformis	slender crabgrass	SP		intermediate	dry	PRES	12
Panicum flexile	old witchgrass	TU	FACU	short			9
Triplasis purpurea	purple sandgrass	PE		short	sandy		4
PERENNIAL FORBS							
Ageratina aromatica	small-leaf white-snakeroot	PR		short			8
Amianthium muscaetoxicum	fly-poison	SP	FAC	intermediate	sandy		6
Arnica acaulis	leopard's-bane	PE	FACU	short	sandy		≤ 2
Asclepias purpurascens	purple milkweed	SP	FACU	intermediate	dry		24
Asclepias variegata	white milkweed	PE	FACU	intermediate			9
Boltonia asteroides	aster-like boltonia	PE	FACW	tall			4
Cardamine pratensis	cuckoo-flower, lady's-smock	TU	OBL	short	wet		≤ 2
Chrysopsis mariana	golden aster	PE	UPL	short	sandy		4
Commelina virginica	Virginia dayflower	PX	FACW	intermediate			≤ 2 (adventive?)
Conoclinium coelestinum	mistflower, wild ageratum	SP	FAC	short			11
Coreopsis rosea	pink tickseed	PX	FACW	short	sandy, wet		≤ 2 (adventive?)
Cypripedium candidum	small white lady's-slipper	PX	OBL	very short or prostrate	calcareous, wet		≤ 2
Desmodium laevigatum	smooth tick-clover, smooth tick-trefoil	TU		intermediate	sandy	HIST	9

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Desmodium nuttallii	Nuttall's tick-trefoil	TU		intermediate			6
Desmodium obtusum		TU		intermediate	sandy	HIST	≤ 2
Desmodium viridiflorum	velvety tick-trefoil	TU		intermediate			≤ 2
Dodecatheon meadia	shooting-star, pride-of-Ohio	PE	FACU	short	calcareous		4
Echinacea laevigata	Appalachian coneflower, smooth purple coneflower	PX		intermediate			≤ 2
Elephantopus carolinianus	elephant's foot	PE	FACU	intermediate			4
Epilobium strictum	downy willow-herb	PR	OBL	short	calcareous, wet		≤ 2
Eryngium aquaticum	marsh eryngo, rattlesnake-master	PX	OBL	intermediate	wet		≤ 2
Eupatorium album	white-bracted eupatorium	PE		short	sandy		≤ 2
Eupatorium godfreyanum	Godfrey's thoroughwort	TU		tall			≤ 2
Eupatorium pilosum	ragged eupatorium, rough boneset	SP	FACW	intermediate	sandy		17
Eupatorium rotundifolium var. *ovatum*	roundleaf eupatorium	TU	FAC-	intermediate	sandy		5
Eupatorium rotundifolium var. *rotundifolium*	roundleaf eupatorium	TU	FAC-	intermediate			5
Euthamia caroliniana	grassleaf goldenrod, coastal plain flat-topped goldenrod	PT	FAC	intermediate			7
Filipendula rubra	queen-of-the-prairie	TU	FACW	tall			≤ 2
Gentiana saponaria	soapwort gentian	PE	FACW	intermediate			16
Gentiana villosa	striped gentian	PE		short			3
Gratiola aurea	goldenpert, hedge hyssop	PE	OBL	very short or prostrate	wet		8
Helianthemum bicknellii	Bicknell's hoary rockrose	PE		short			5
Helianthemum propinquum	low frostweed	TU		very short or prostrate	sandy		8

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Hieracium umbellatum	Canada hawkweed	TU		tall			≤ 2
Houstonia purpurea var. *purpurea*	purple bluets, southern bluets	TU		very short or prostrate			≤ 2
Iris prismatica	slender blue flag	PE	OBL	short	wet		4
Lathyrus palustris	marsh pea, vetchling	PE	FACW+	intermediate			8
Lathyrus venosus	veiny pea, veiny vetchling	TU	FACW	intermediate			5
Lechea minor	thyme-leaf pinweed	PE		short	sandy	HIST	5
Lechea villosa	hairy pinweed	SP		short	dry, sandy		12
Lespedeza angustifolia	narrowleaf bush-clover	PE	FAC	intermediate	sandy	PRES	≤ 2
Lespedeza stuevei	tall bush-clover	PX		intermediate			≤ 2
Liatris scariosa	northern blazing-star	PT	UPL	short			≤ 2
Linum intercursum	sandplain wild flax	PE		short			≤ 2
Lobelia kalmii	brook lobelia	PE	OBL	very short or prostrate	calcareous, wet		3
Lobelia nuttallii	Nuttall's lobelia	PX	FACW	short	sandy, wet		≤ 2
Lobelia puberula	downy lobelia	PE	FACW-	tall	sandy		4
Lupinus perennis	blue lupine, sundial lupine	PR		short	sandy	HIST	8
Lysimachia hybrida	lanceleaf loosestrife	PT	OBL	tall	wet		11
Lythrum alatum	winged loosestrife	PE	FACW+	short	wet		5
Maianthemum stellatum	starflower	SP		short	sandy, riparian		10
Matelea obliqua	anglepod, oblique milkvine, climbing milkvine	PE		(climbing)	calcareous	HIST	≤ 2
Monarda punctata	spotted bee-balm	PE	UPL	intermediate	sandy		≤ 2
Oxypolis rigidior	cowbane, water-dropwort	PT	OBL	tall	wet		8
Packera anonyma	Appalachian groundsel, plain ragwort	PR	UPL	short			5

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Packera obovata	roundleaf ragwort, squaw-weed	SP	FACU–	short	calcareous		17
Parnassia glauca	grass-of-parnassus	PE	OBL	short	calcareous, wet		7
Parthenium integrifolium	American fever-few	PX		intermediate			≤ 2
Pedicularis lanceolata	swamp lousewort, wood-betony	PE	FACW	short	wet		11
Penstemon laevigatus	eastern beard-tongue	TU	FACU	intermediate			≤ 2
Phaseolus polystachios	wild bean, thicket bean	PE		very tall		HIST	17
Phlox pilosa	downy phlox, prairie phlox	PE	FACU	short			12
Platanthera ciliaris	yellow fringed-orchid	PT	FACW	intermediate			9
Platanthera cristata	crested fringed-orchid	PX	FACW+	short			≤ 2
Platanthera peramoena	purple fringeless orchid	PT	FACW	intermediate			≤ 2
Polymnia canadensis	leaf-cup	SP		tall			
Potentilla anserina	silverweed	PR	OBL	very short or prostrate	sandy, wet		≤ 2
Potentilla arguta	tall cinquefoil	SP	UPL	intermediate	dry		6
Prenanthes serpentaria	lion's-foot, cankerweed	PT		tall		HIST	5
Pycnanthemum clinopodioides	basil mountain-mint	PX		intermediate		HIST	≤ 2
Pycnanthemum verticillatum var. *pilosum*	whorled mountain-mint	PX	FAC	intermediate			≤ 2
Ranunculus flammula var. *reptans*	creeping spearwort	PX	FACW	short	sandy, riparian		≤ 2
Ratibida pinnata	prairie coneflower	PX		tall			≤ 2
Rudbeckia fulgida var. *fulgida*	eastern coneflower	TU	FAC	intermediate			6
Ruellia strepens	limestone petunia	PT	FAC	intermediate	calcareous, wet		4
Samolus parviflorus	water pimpernel	PE	OBL	very short or prostrate	wet		8

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Scutellaria leonardii	small skullcap	SP		very short or prostrate	riparian		12
Senna marilandica	southern wild senna	PE	FAC+	tall			≤ 2
Sericocarpus linifolius	narrowleaf white-topped aster	PE		short	sandy, wet		7
Sisyrinchium atlanticum	eastern blue-eyed-grass	PE	FACW	short	sandy		3
Sisyrinchium fuscatum	sand blue-eyed-grass	PX	FACU	short	sandy		≤ 2
Solidago rigida	stiff goldenrod	PE	UPL	tall			7
Solidago simplex ssp. *randii* var. *racemosa*	sticky goldenrod	PE		short			≤ 2
Solidago speciosa	showy goldenrod	PT		tall			5
Solidago uliginosa	bog goldenrod	TU	OBL	tall	wet		6
Spiranthes lucida	shining ladies'-tresses	TU	FACW	very short or prostrate	calcareous, wet		9
Spiranthes magnicamporum	Great Plains ladies'-tresses	PX	FACU-	very short or prostrate	calcareous, wet		≤ 2
Spiranthes tuberosa	slender ladies'-tresses	PX	FACU-	very short or prostrate			≤ 2
Spiranthes vernalis	spring ladies'-tresses	PE	FAC	short	sandy		7
Stachys hyssopifolia var. *ambigua*	hedge-nettle	PX	FACW+	short			≤ 2 (adventive?)
Stachys hyssopifolia var. *hyssopifolia*	hedge-nettle, woundwort	PX	FACW+	short			≤ 2 (adventive?)
Stenanthium gramineum	featherbells	TU	FACW	tall			≤ 2
Strophostyles umbellata	wild bean, pink fuzzy-bean	PE	FACU	intermediate	sandy		11
Stylosanthes biflora	pencil-flower, sidebeak pencil-flower	PE		short	sandy	HIST	21
Symphyotrichum dumosum	bushy aster, rice button aster	PE	FAC	short		HIST	7

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Symphyotrichum novi-belgii var. *novi-belgii*	New York aster	PT	FACW+	tall	wet		5
Tradescantia ohiensis	Ohio spiderwort, blue-jacket	SP	FAC	short	riparian		
Trollius laxus	spreading globe-flower	PE	OBL	short	calcareous, wet		7
Vernonia glauca	Appalachian ironweed, tawny ironweed, broadleaf ironweed	PE		tall		HIST PRES	9
Vicia americana	purple vetch	SP		intermediate	riparian		8
ANNUAL, BIENNIAL AND OTHER SHORT-LIVED FORBS							
Agalinis auriculata	eared false-foxglove	PE		short			≤ 2
Agalinis decemloba	Blue Ridge false-foxglove	PX	FACU	short			≤ 2 (adventive?)
Agalinis paupercula	small-flowered false-foxglove	PE	FACW+	short			≤ 2
Ammannia coccinea	tooth cup, valley redstem	PT	OBL	short	wet		≤ 2
Bidens laevis	showy bur-marigold	TU	OBL	intermediate	wet		13
Castilleja coccinea	Indian paintbrush	PT	FAC	short			28
Chenopodium capitatum	Indian-paint, strawberry-blite	TU		short			≤ 2
Cirsium horridulum	yellow thistle, horrible thistle	PE	FACU-	tall	sandy		4
Cuscuta campestris	five-angled dodder	PT		(climbing)		HIST	≤ 2
Gentianella quinquefolia	stiff gentian, ague-weed	SP	FAC	short			5
Gentianopsis crinita	eastern fringed gentian	SP	OBL	short	wet		21
Geranium bicknellii	Bicknell's cranesbill	PE		very short or prostrate			≤ 2
Lactuca hirsuta	downy lettuce	TU		tall	calcareous, wet		≤ 2
Linaria canadensis	old-field toadflax	SP		short	sandy, riparian	HIST	14
Linum sulcatum	grooved yellow flax	PE		short	sandy		≤ 2

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Minuartia michauxii	rock sandwort	SP		very short or prostrate	dry		4
Oenothera oakesiana	evening-primrose	TU	FACU-	short			≤ 2
Paronychia fastigiata var. nuttallii	whitlow-wort	PE		very short or prostrate	sandy		≤ 2
Phacelia dubia	scorpion-weed, small flowered phacelia	SP		very short or prostrate	shaly		7
Phacelia purshii	Miami-mist	SP		short			
Phyllanthus caroliniensis	Carolina leaf-flower	PE		very short or prostrate			3
Physalis pubescens var. integrifolia	hairy ground-cherry	SP	FACU–	short	riparian		5
Polygala cruciata	crossleaf milkwort	PE	FACW+	very short or prostrate	wet		8
Polygala curtissii	Curtis's milkwort	PE		very short or prostrate	sandy		≤ 2
Polygala incarnata	pink milkwort	PE	UPL	short			≤ 2
Polygala polygama	bitter milkwort, racemed milkwort	PE	UPL	very short or prostrate			≤ 2
Polygonella articulata	jointweed	PE		short	sandy		≤ 2
Polygonum ramosissimum ssp. *ramosissimum*	bushy knotweed	PX	FAC	tall	sandy		≤ 2
Ranunculus pensylvanicus	bristly crowfoot	SP	OBL	intermediate	wet		
Rotala ramosior	tooth-cup, lowland rotala	PR	OBL	very short or prostrate	wet	HIST PRES	4
Trifolium reflexum	buffalo clover	PX		short			≤ 2

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
PERENNIAL RUSHES AND SEDGES							
Carex alata	broad-winged sedge	PT		tall	calcareous, wet		≤ 2
Carex bicknellii	Bicknell's sedge	PE		intermediate			≤ 2
Carex brevior	shortbeak sedge	PT	UPL	intermediate			7
Carex bullata	bull sedge	PE	OBL	short	wet		≤ 2
Carex buxbaumii	brown sedge	PR	OBL	intermediate	wet		13
Carex cephaloidea	thinleaf sedge	SP	FAC+	short	dry, riparian		4
Carex conjuncta	soft fox sedge	SP	FACW	intermediate		PRES	13
Carex haydenii	cloud sedge	PT	OBL	intermediate	wet		3
Carex interior	inland sedge	SP	OBL	short	wet		6
Carex leavenworthii	Leavenworth's sedge	SP		short		HIST PRES	15
Carex longii	Long's sedge	TU	OBL	intermediate	wet		5
Carex lupuliformis	false hop sedge	TU	FACW+	intermediate	wet		≤ 2
Carex meadii	Mead's sedge	PE	FAC	short			7
Carex molesta	field oval sedge, troublesome sedge	SP		intermediate	dry		16
Carex nigromarginata	black edge sedge	SP	UPL	very short or prostrate	dry	HIST	12
Carex polymorpha	variable sedge	PT	FACU	short	sandy		≤ 2
Carex prairea	prairie sedge	PT	FACW	intermediate	calcareous, wet		7
Carex richardsonii	Richardson's sedge	PE	UPL	very short or prostrate			≤ 2
Carex shortiana	Short's sedge	PR	FAC	short	wet		4
Carex sprengelii	Sprengel's sedge	PR	FACU	intermediate			6
Carex tenera var. tenera	marsh straw sedge, quill sedge	SP	FAC	short			

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Carex tetanica	Wood's sedge	PT	FACW	short	calcareous, wet		9
Carex tonsa var. tonsa	shaved sedge	SP		tall		HIST	16
Cyperus echinatus	globe flatsedge, umbrella sedge	SP	FACU	intermediate	dry		16
Cyperus houghtonii	Houghton's flatsedge	PE		intermediate	sandy		≤ 2
Cyperus lancastriensis	umbrella sedge	TU	FACU	intermediate			6
Cyperus schweinitzii	Schweinitz's flatsedge	PR	FACU	intermediate	sandy		≤ 2
Eleocharis tenuis var. *verrucosa*	slender spike-rush	PE	FACW+	very short or prostrate			≤ 2
Eriophorum gracile	slender cotton-grass	PE	OBL	short	wet		12
Juncus biflorus	grass rush	PT	FACW	intermediate	wet		7
Juncus dichotomus	forked rush	PE	FACW-	short	sandy		17
Luzula bulbosa	woodrush	PE	FACU	very short or prostrate			≤ 2
Rhynchospora recognita	beak-rush	TU	FACW	intermediate	sandy, wet		5
Scleria pauciflora	few-flowered nut-rush	PT	FACU+	short			5
Scleria triglomerata	whip-grass, nut-rush	TU	FAC	intermediate	sandy		12
ANNUAL SEDGES							
Eleocharis engelmannii	Engelmann's spike-rush	SP	FACW+	very short or prostrate		HIST	9
Scleria muhlenbergii	reticulated nut-rush	PE	OBL	short	sandy, wet		5
Scleria verticillata	whorled nut-rush	PE	OBL	short	calcareous, wet		3

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
NON-FLOWERING HERBACEOUS PERENNIALS							
Botrychium multifidum	leathery grape fern, northern grape fern	SP	FACU	very short or prostrate			
Botrychium simplex	least moonwort, least grape-fern	SP	FACU	short			6
Lycopodiella alopecuroides	foxtail bog clubmoss	PE	FACW+	very short or prostrate			≤ 2
Ophioglossum vulgatum	southern adder's-tongue	PR	FACW	very short or prostrate			≤ 2
SHRUBS, SMALL TREES, AND WOODY VINES							
Amelanchier obovalis	coastal juneberry, coastal shadbush	PE	FACU	tall			≤ 2
Baccharis halimifolia	groundsel-tree, eastern baccharis	PR	FACW	very tall	saline	HIST	4 (adventive?)
Ceanothus americanus	New Jersey tea	SP		intermediate	shaly		25
Celastrus scandens	American bittersweet	SP	FACU–	very tall	dry		26
Crataegus mollis	downy hawthorn	TU	FACU	very tall	calcareous		≤ 2
Hypericum densiflorum	bushy St. John's-wort	PR	FAC+	tall	wet		≤ 2
Hypericum stragulum	St. Andrew's-cross	PT		very short or prostrate	sandy	HIST PRES	7
Juniperus communis	common juniper	TU		very tall			10
Lyonia mariana	staggerbush	PE	FAC-	tall			7
Prunus angustifolia	Chickasaw plum	SP		very tall			
Prunus maritima	beach plum	PE		tall			≤ 2
Prunus pumila var. *depressa*	sand cherry	PE		tall	sandy, riparian		7
Ptelea trifoliata	hoptree, wafer-ash	PT	FAC	very tall			4
Rhamnus lanceolata	lanceolate buckthorn	PE		tall			3

taxon	common name(s)	state status	wetland status	maximum height category	specialized tolerance(s)	Valley Forge status	frequency among 99 historical reference sites
Rosa virginiana	wild rose, pasture rose	TU	FAC	tall			8
Rubus cuneifolius	sand blackberry	PE	UPL	intermediate	sandy	HIST PRES	≤ 2
Salix petiolaris	slender willow	SP	FACW+	very tall			
Symphoricarpos albus var. albus	snowberry	SP	FACU–	intermediate			

Appendix F. Sites in the Greater Piedmont Used in Reconstructing Historical Grassland and Meadow Species Composition

Herbarium records were used to identify 99 historical sites in southeastern Pennsylvania that were rich in native grassland and meadow indicator species, omitting serpentine grasslands (see *Methods* and *Results*).

The list is organized by physiographic section (see Table 1, page 8). *Indicators* are the 620 species verified at three or more of these sites, out of the 755 native vascular plant species that live solely or predominantly in grassland and meadow habitats in the Greater Piedmont. *Species richness* is how many of the 620 indicators are documented at each site (range: 11–367) by voucher specimens in herbaria such as the Academy of Natural Sciences (source: Pennsylvania Flora Project 2007; T. A. Block, personal communication).

PHYSIOGRAPHIC SECTION site name	county/ies	bedrock category	species richness of native grassland and meadow indicators
PIEDMONT PROVINCE: PIEDMONT LOWLAND SECTION			
Downingtown	Chester	limestone, dolomite	96
Lancaster	Lancaster	limestone, dolomite	137
South Valley Hills	Chester	schist, phyllite	104
PIEDMONT PROVINCE: PIEDMONT UPLAND SECTION			
Coatesville	Chester	quartzite	94
Hickory Hill	Chester	schist, phyllite	24
Kennett Square	Chester	limestone, dolomite	75
Northbrook	Chester	gneiss, granite	16
Peacedale	Chester	schist, phyllite	38
Westtown	Chester	schist, phyllite	125
Chadds Ford	Chester, Delaware	gneiss, granite	84
Elam	Delaware	sand, gravel	296
Glen Riddle	Delaware	gneiss, granite	34
Johnsons Corner	Delaware	sand, gravel	15
Swarthmore	Delaware	schist, phyllite	208
Haverford	Delaware, Montgomery	schist, phyllite	150
Safe Harbor	Lancaster	quartzite	81
Tucquan Creek	Lancaster	schist, phyllite	69
McCalls Ferry	Lancaster, York	schist, phyllite	192
York Furnace	Lancaster, York	schist, phyllite	82
Melrose Park	Montgomery	schist, phyllite	66
Germantown	Philadelphia	schist, phyllite	103
Shawmont	Philadelphia	schist, phyllite	203

PHYSIOGRAPHIC SECTION site name	county/ies	bedrock category	species richness of native grassland and meadow indicators
Wissahickon Creek	Philadelphia	schist, phyllite	230
PIEDMONT PROVINCE: GETTYSBURG-NEWARK LOWLAND SECTION			
Gettysburg	Adams	diabase	153
Neversink Station	Berks	quartzite	11
White Bear	Berks	sandstone	105
French Creek	Berks, Chester	conglomerate	234
Argus	Bucks	diabase	71
Doylestown	Bucks	sandstone	165
Monroe	Bucks	limestone, dolomite	80
New Hope	Bucks	shale, mudstone, siltstone	103
Nockamixon	Bucks	diabase	29
Pleasant Valley	Bucks	shale, mudstone, siltstone	86
Point Pleasant	Bucks	argillite	149
Quakertown	Bucks	shale, mudstone, siltstone	90
Rock Hill	Bucks	diabase	132
Sellersville	Bucks	hornfels	173
Upper Black Eddy	Bucks	hornfels	191
Yardley	Bucks	sand, gravel	101
Finland	Bucks, Montgomery	diabase	77
Telford	Bucks, Montgomery	shale, mudstone, siltstone	107
Phoenixville	Chester	sandstone	92
Brickerville	Lancaster	shale, mudstone, siltstone	111
Conewago	Lancaster	diabase	66
Glasgow	Montgomery	argillite	168
Green Lane	Montgomery	diabase	18
Hatfield	Montgomery	shale, mudstone, siltstone	92
Pennsburg	Montgomery	shale, mudstone, siltstone	70
Schwenksville	Montgomery	shale, mudstone, siltstone	138
Sumneytown	Montgomery	diabase	128
Willow Grove	Montgomery	gneiss, granite	182
ATLANTIC COASTAL PLAIN PROVINCE: LOWLAND AND INTERMEDIATE UPLAND SECTION			
Bristol	Bucks	sand, gravel	191
Croydon	Bucks	sand, gravel	44
Eddington	Bucks	sand, gravel	87
Morrisville	Bucks	sand, gravel	122
Tullytown	Bucks	sand, gravel	135
Turkey Hill	Bucks	sand, gravel	45

PHYSIOGRAPHIC SECTION site name	county/ies	bedrock category	species richness of native grassland and meadow indicators
Chester	Delaware	schist, phyllite	66
Darby	Delaware	schist, phyllite	66
Linwood	Delaware	sand, gravel	82
Secane	Delaware	schist, phyllite	94
Upper Darby	Delaware	schist, phyllite	120
Hog Island	Delaware, Philadelphia	sand, gravel	37
Tinicum	Delaware, Philadelphia	sand, gravel	37
Black Oak Park	Philadelphia	schist, phyllite	38
Girard Point	Philadelphia	sand, gravel	27
Greenwich Point	Philadelphia	sand, gravel	56
Holmesburg	Philadelphia	sand, gravel	87
RIDGE AND VALLEY PROVINCE: GREAT VALLEY SECTION			
Bernville	Berks	shale, mudstone, siltstone	234
Fleetwood	Berks	limestone, dolomite	159
Neversink Mountain	Berks	quartzite	44
Reading	Berks	limestone, dolomite	187
Grantham	Cumberland, York	limestone, dolomite	161
Harrisburg	Dauphin	shale, mudstone, siltstone	113
Chambersburg	Franklin	limestone, dolomite	51
Mercersburg	Franklin	limestone, dolomite	293
Williamson	Franklin	limestone, dolomite	20
Jonestown	Lebanon	shale, mudstone, siltstone	140
Allentown	Lehigh	limestone, dolomite	258
Emmaus	Lehigh	limestone, dolomite	113
Friedensville	Lehigh	limestone, dolomite	83
Lanark	Lehigh	limestone, dolomite	78
Lehigh Furnace	Lehigh	shale, mudstone, siltstone	81
Lowhill	Lehigh	shale, mudstone, siltstone	113
Mountainville	Lehigh	limestone, dolomite	135
Scherersville	Lehigh	limestone, dolomite	21
Slatington	Lehigh	shale, mudstone, siltstone	167
Trexlertown	Lehigh	limestone, dolomite	63
Wescoesville	Lehigh	limestone, dolomite	81
Bethlehem	Lehigh, Northampton	limestone, dolomite	292
Easton	Northampton	limestone, dolomite	367
Freemansburg	Northampton	limestone, dolomite	38
Hellertown	Northampton	limestone, dolomite	221

PHYSIOGRAPHIC SECTION site name	county/ies	bedrock category	species richness of native grassland and meadow indicators
Johnsonville	Northampton	limestone, dolomite	141
Mount Bethel	Northampton	limestone, dolomite	93
Riverton	Northampton	limestone, dolomite	153
Seidersville	Northampton	limestone, dolomite	83
Slateford	Northampton	shale, mudstone, siltstone	122
NEW ENGLAND PROVINCE: READING PRONG SECTION			
Raubsville	Northampton	limestone, dolomite	85

Appendix G. Butterflies Other Than Those of Special Conservation Concern Recently Confirmed in or Potentially Inhabiting Valley Forge Grasslands and Meadows

Appendix G. Butterflies Other Than Those of Special Conservation Concern Recently Confirmed in or Potentially Inhabiting Valley Forge Grasslands and Meadows

Data are from surveys of the park (Ruffin 1994; Anonymous 1996) and a compilation of surveys throughout Pennsylvania (Wright 2007). Butterfly species of special conservation concern are listed in Table 21 (pp. 58-60).

taxon	common name	larval host plants or prey*	local occurrence†
Papilionidae (swallowtails)			
Battus philenor	pipevine swallowtail	*Aristolochia*	park
Papilio appalachiensis	Appalachian tiger swallowtail	unknown	ecoregion
Papilio glaucus	eastern tiger swallowtail	*Prunus serotina, Liriodendron tulipifera*	park
Papilio palamedes	Palamedes swallowtail	*Sassafras albidum, Lindera benzoin*	ecoregion
Papilio polyxenes	black swallowtail	Apiaceae	park
Papilio troilus	spicebush swallowtail	*Sassafras albidum, Lindera benzoin*	park
Pieridae (whites and sulphurs)			
Abaeis nicippe	sleepy orange	*Chamaecrista*	county
Colias eurytheme	orange sulphur	Fabaceae	park
Colias philodice	clouded sulphur	*Trifolium repens*	park
Nathalis iole	dainty sulphur	Asteraceae, including *Bidens, Helenium*	ecoregion
Phoebis sennae	cloudless sulphur	*Chamaecrista*	park
Pieris rapae	cabbage white	*Brassicaceae*	park
Pyrisitia lisa	little yellow	*Chamaecrista fasciculata, C. nictitans*	county
Zerene cesonia	southern dogface	Fabaceae	county
Lycaenidae (harvesters, coppers, hairstreaks, blues)			
Atlides halesus	great purple hairstreak	*Phoradendron*	ecoregion
Calycopis cecrops	red-banded hairstreak	detritus, including dead leaves of *Rhus*	park

* B. Leppo, personal communication; Ruffin 1994; Opler et al. 2006
† Smallest confirmed area of local occurrence: **park** = within VAFO; **county** = within Chester or Montgomery Counties; **ecoregion** = in Greater Piedmont

taxon	common name	larval host plants or prey*	local occurrence[†]
Celastrina ladon	spring azure	*Cornus, Ceanothus americanus, Viburnum*	park
Celastrina lucia	northern spring azure	unknown	ecoregion
Celastrina neglecta	summer azure	*Cornus racemosa, Ceanothus americanus*	county
Cupido comyntas	eastern tailed blue	herbaceous Fabaceae	park
Feniseca tarquinius	harvester	woolly aphids, usually on *Alnus* or *Fagus grandifolia*	park
Glaucopsyche lygdamus	silvery blue	*Vicia*	county
Lycaena phlaeas	American copper	*Rumex*	park
Satyrium acadica	Acadian hairstreak	*Salix,* including *S. nigra ,S. sericea*	county
Satyrium calanus	banded hairstreak	*Quercus, Carya*	park
Satyrium caryaevorum	hickory hairstreak	mainly *Carya,* also *Quercus, Castanea, Fraxinus*	park
Satyrium favonius	southern hairstreak	*Quercus*	county
Satyrium liparops	striped hairstreak	Ericaceae, *Prunus*	park
Strymon melinus	gray hairstreak	Fabaceae	park
Nymphalidae (snouts, heliconians, fritillaries, brush-foots, admirals, emperors, satyrs, monarchs)			
Aglais milberti	Milbert's tortoiseshell	*Urtica dioica*	county
Agraulis vanillae	gulf fritillary	*Passiflora*	ecoregion
Asterocampa celtis	hackberry emperor	*Celtis*	park
Boloria bellona	meadow fritillary	*Viola*	park
Boloria selene	silver-bordered fritillary	*Viola*	county
Cercyonis pegala	common wood nymph	Poaceae	park
Danaus gilippus	queen	*Asclepias, Cynanchum laeve, Matelea obliqua*	ecoregion
Danaus plexippus	monarch	*Asclepias*	park
Euptoieta claudia	variegated fritillary	*Viola, Passiflora*	park
Junonia coenia	common buckeye	*Agalinis, Linaria, Plantago*	park
L. arthemis ssp. intergrades	hybrid purple (partial bands)	*Prunus, Populus, Quercus, Crataegus, Vaccinium stamineum, Betula, Salix, Tilia, Amelanchier*	county
Libytheana carinenta	American snout	*Celtis*	park

taxon	common name	larval host plants or prey*	local occurrence†
Limenitis a. astyanax	red-spotted purple	*Prunus, Salix*	park
Limenitis archippus	viceroy	*Salix*	park
Limenitis arthemis-like	white admiral (full bands)	*Prunus, Populus, Quercus, Crataegus, Vaccinium stamineum, Betula, Salix, Tilia, Amelanchier*	county
Megisto cymela	little wood satyr	Poaceae	park
Nymphalis antiopa	mourning cloak	*Salix*	park
Phyciodes batesii	tawny crescent	*Symphyotrichum undulatum*	county
Phyciodes tharos	pearl crescent	*Symphyotrichum*	park
Polygonia comma	comma	*Ulmus, Urtica*	park
Polygonia interrogationis	question mark	*Urtica, Ulmus, Celtis*	park
Roddia vaualbum	Compton's tortoiseshell	*Populus, Salix, Betula populifolia, B. papyrifera*	park
Satyrodes appalachia	Appalachian eyed brown	*Carex*	park
Speyeria cybele	great spangled fritillary	*Viola*	park
Vanessa atalanta	red admiral	Urticaceae and possibly *Humulus*	park
Vanessa cardui	painted lady	*Cirsium, Carduus*	park
Vanessa virginiensis	American lady	*Anaphalis margaritacea* and other Asteraceae	park
Hesperiidae (skippers)			
Achalarus lyciades	hoary edge	mostly *Desmodium,* occasionally *Lespedeza, Baptisia*	park
Amblyscirtes hegon	pepper and salt skipper	Poaceae	ecoregion
Anatrytone logan	Delaware skipper	Poaceae, including Andropogon gerardii, Panicum virgatum	county
Ancyloxypha numitor	least skipper	*Poa, Leersia and other Poaceae*	park
Atalopedes campestris	sachem	Poaceae	park
Atrytone arogos	Arogos skipper	perhaps *Calamovilfa brevipilis*	ecoregion
Calpodes ethlius	Brazilian skipper	unknown in Northeast	ecoregion
Epargyreus clarus	silver-spotted skipper	Fabaceae, including *Robinia pseudoacacia*	park
Erynnis baptisiae	wild indigo duskywing	*Baptisia tinctoria*	park
Erynnis brizo	sleepy duskywing	*Quercus ilicifolia, Q. velutina*	park

taxon	common name	larval host plants or prey*	local occurrence[†]
Erynnis horatius	Horace's duskywing	*Quercus*	park
Erynnis icelus	dreamy duskywing	*Populus, Salix,* sometimes *Betula, Robinia pseudoacacia*	park
Erynnis juvenalis	Juvenal's duskywing	mainly *Quercus,* sometimes *Carya*	park
Erynnis zarucco	Zarucco duskywing	Fabaceae, including *Robinia pseudoacacia*	county
Euphyes conspicua	black dash	*Carex stricta*	county
Euphyes vestris	dun skipper	*Carex, Cyperus*	park
Hesperia attalus	dotted skipper	Poaceae	ecoregion
Hylephila phyleus	fiery skipper	Poaceae	park
Lerema accius	clouded skipper	Poaceae	county
Oligoria maculata	twin-spotted skipper	Poaceae	ecoregion
Panoquina ocola	Ocola skipper	Poaceae	county
Pholisora catullus	common sootywing	*Amaranthus, Chenopodium*	park
Poanes hobomok	Hobomok skipper	*Panicum, Eragrostis, Tridens flavus*	park
Poanes viator	broad-winged skipper	*Carex lacustris*	county
Poanes zabulon	Zabulon skipper	Poaceae, including *Eragrostis, Tridens flavus, Elymus, Agrostis*	park
Polites origenes	crossline skipper	*Tridens flavus, Schizachyrium scoparium* and other Poaceae	park
Polites peckius	Peck's skipper	*Poa, Leersia* and other Poaceae	park
Polites themistocles	tawny-edged skipper	Poaceae	park
Pompeius verna	little glassywing	*Tridens flavus* and other Poaceae	park
Pyrgus centaureae	grizzled skipper	*Fragaria virginiana, Potentilla canadensis*	ecoregion
Pyrgus communis	common checkered skipper	Malvaceae	park
Staphylus hayhurstii	Hayhurst's scallopwing	*Chenopodium album*	county
Thorbyes confusis	confused cloudywing	*Lespedeza*	ecoregion
Thorybes pylades	northern cloudywing	*Desmodium, Lespedeza* and other Fabaceae	park
Thymelicus lineola	European skipper	*Agrostis* and other Poaceae	park
Urbanus proteus	long-tailed skipper	*Desmodium, Clitoria mariana* and other Fabaceae	park
Wallengrenia egeremet	northern broken dash	*Panicum* and other Poaceae	park

Appendix H. Notes on Restoration and Adaptive Management Approaches Consistent with Desired Conditions

Adaptive management, in simplest terms, consists of implementing a set of actions, monitoring the results, reconsidering the methods in light of those results, and adjusting methods in the next round of implementation accordingly. It is the only management approach that can truly be said to be science-based, because it incorporates the scientific method to continually test methods' effectiveness under a park's or other management unit's unique set of conditions and either discard or improve management protocols that prove ineffective.

The most effective grassland/meadow restoration and management methods are those that set the stage for nature to do most of the work. An agricultural paradigm, with native plant mixtures and wildlife habitat elements viewed as "crops" requiring intensive energy input every year for the foreseeable future, is unrealistic at any scale larger than a small garden or ornamental planting. For instance, relying on such methods as broadcast herbiciding, plowing, seeding and repeated herbicide application to combat invasive species may be a losing proposition where soils have been altered by centuries of cultivation. Instead, taking steps to bring about a gradual reduction in soil nutrient availability to pre-agricultural levels will get at the root of the problem by taking away invasive species' competitive advantage over native grassland/meadow plants. This may involve intensive labor, especially at first and sporadically thereafter, using methods such as biomass harvest, high-intensity prescribed burning, soil scarification, organic matter removal and recruiting the help of soil microbes by adding a carbon source. However, such an approach is likely to be more efficient in the long term than aspiring to lasting change by treating symptoms rather than underlying causes.

This appendix expands on certain restoration and management concepts associated with achieving and sustaining desired conditions that go beyond a more conventional field management approach.

Simulating Effects of Historical Disturbance Regimes

Dormant-season mowing, prescribed burning, spot-herbiciding and seedbank augmentation are the mainstays of the management toolkit for simulating the effects of natural disturbances that created and sustained native grasslands and meadows in eastern North America. Other, less frequently used methods include prescribed grazing, hand-pulling of undesired plants, mechanical soil scarification, organic matter removal and soil carbon addition. All of these methods affect ecosystems in some ways that are similar and others that are different from the effects of the natural disturbances under which native grassland/meadow species evolved.

One of the key ways in which artificial disturbance (ecological management) often differs from historical disturbance regimes is in its relative uniformity. Mowing tends to be applied based on an agricultural or horticultural model—every available acre mowed on an unvarying schedule—and vast areas of uniform turf are the frequent result. Prescribed burning also tends toward uniformity, with the same non-overlapping burn units used year after year and managers striving for a single, ideal return interval (number of years between consecutive burns on the same unit of land). Such practices may enhance logistical convenience but they are ineffective as means of achieving and sustaining desired conditions. High patch diversity was the norm for millions of years and is essential to accommodate the varied habitat needs across the full range of native grassland/meadow plant and animal species. Desired conditions require patchy management—spatial and temporal irregularity in intensity, type and return interval of disturbance.

One possible approach is keeping management units (fields) small and varying which units receive which treatments in a given year. Another is grouping some units but not others into larger clusters among which different treatment regimes are allocated in one year, and then grouping them into different but overlapping clusters for the next year's treatments. The result is that some fields are subjected to more severe overall disturbance effects than others in a given 5- to 10-year period. Over longer periods, all units eventually experience periods of severe disturbances in rapid succession and "rest" periods of less severe or less frequent disturbance.

For fire and other disturbances, the minimum return interval is defined by how long it takes for sufficient fuel to accumulate to support the spread of fire to cover a significant portion of the landscape, and the maximum return interval by how long it takes within a given local set of conditions for succession to reach the tipping point beyond which fire no longer results in the return of a grassland or meadow community without additional, costly measures.

MacDougall and Turkington (2007) pointed out major potential challenges in restoring fire to formerly fire-maintained landscapes:

> The arguments for burning are often based on the assumption that its effects are irreplaceable (e.g., soil nutrients, seed germination, plant mortality). However, this is not always tested … Further, there are potential risks with the use of fire. First, there is no guarantee that its effects on native plant and animal species will be fully positive due to the small population sizes typically found in remnant areas. Second, if prescribed fires escape to surrounding areas, as occasionally happens, the economic costs can be substantial and the subsequent wariness of the public may prevent further application. Determining whether and how to use fire, therefore, has both ecological and practical relevance and needs to be tested against alternative methods for restoring native grasslands. [pp. 263-264]

They presented results of a five-year field experiment examining the impacts of burning versus two other treatments—cutting and raking and the manual removal of the dominant species—on the restoration of native ground flora in fire-suppressed oak savanna in British Columbia (MacDougall and Turkington 2007). They tested two effects critical to restoration and reclamation—controlling dominant grasses and increasing subordinate native flora—by manipulating the season of treatment and conducting treatments across a range of soil depths. They found no significant difference among treatments in effectiveness at suppressing invasives and increasing native plant growth, hypothesizing that light was the primary limiting resource and all treatments increased its availability. However, effectiveness of all treatments varied with the timing of application and soil depth. Summer disturbances struck the most invasive of the nonnative plants, mainly perennial C_3 grasses, just before seed set, causing nearly 100% mortality. Positive responses by native species were significantly greater on shallow soils where native diversity was already higher before treatment. Although not fully transferable to VAFO, these results emphasize the importance of testing the effectiveness of alternative restoration treatments as part of an adaptive management program.

There is no doubt that grazing and browsing by wild herbivores—deer (Anderson et al. 2001, 2005), voles, mice, shrews and slugs (Bramble et al. 1996; Howe et al. 2006) and insects—is already exerting an effect on plant species' relative abundances in the park's grasslands and meadows, but it is not clear than any of these animals are enhancing patch diversity as large herbivores formerly did (de Knegt et al. 2008). Conducting trials of locally high-intensity, overall low-intensity prescribed grazing at VAFO would be a valuable contribution to restoration science as well as to patch and species diversity in the park. Mimicking the historical pattern of localized high-intensity grazing also has a logistical advantage—smaller areas mean lower costs for portable fencing.

Prescribed grazing is widely used in native grassland reclamation and restoration in Europe and to a far lesser degree in North America, so far mainly in California. How far behind American grassland restorationists are in the use of this method compared with their European counterparts is reflected in the fact that prescribed grazing goes unmentioned in the 463 pages of *The Tallgrass Restoration Handbook for Prairies, Savannas, and Woodlands* (Packard and Mutel 2005) and nearly all of the relevant items found in a Google Scholar search on the keywords grazing + grassland + restoration concerned research and practice in the United Kingdom, Finland, France, Germany, Italy, the Netherlands and Spain. However, there is a small but growing interest in hiring small herds of sheep, cattle or goats for stints at vegetation management for biodiversity conservation purposes in the northeastern United States. Research is much needed. VAFO could provide opportunities for such research as part of adaptive management. This would require durable fencing designed for portability and hiring small herds of grass-grazing species. Bison require more permanent fencing and are expensive and difficult to handle, but various cattle breeds are more docile and their selectivity and other ecologically significant behaviors may differ somewhat among breeds.

If species diversity is to be sustained at desired high levels, management must be aimed to fall more heavily on dominant species and spare subordinate species. Except for hand-weeding or spot-herbiciding, which typically target invasive nonnative species growing in spatially discrete patches, grazing and browsing are the most selective disturbances in the manager's toolkit to deal with "over-dominance" by one or a small group of native species. This selectivity can be used to sustain high levels of native species diversity if grazers disproportionately consume the dominant plants, for instance, grass grazers (bison, cattle) where grasses are most abundant, forb grazers (deer, sheep) where forbs predominate, and browsers (deer, goats) where woody plants are present. Burning is selective to a somewhat lesser degree; its selectivity is related to the season when it is applied. Fire favors warm-season grasses and late-flowering forbs if applied in spring and can benefit cool-season grasses and spring-flowering forbs if done in late summer or early fall. The season of mowing may influence how various species and functional groups respond but mowing is least selective because it is associated with lower rates of plant mortality than grazing, browsing or burning.

Spot-herbiciding is the most selective management method and it is the most labor- and time-intensive. However, it is the only effective way of targeting present extreme problem spots, for instance, the massive and growing infestation by Chinese silvergrass (*Miscanthus sinensis*) in the southwestern part of the park. Invasive species that tend to occur in monospecific patches are also appropriate targets of spot-herbiciding, including Canada thistle (*Cirsium arvense*) and common reed (*Phragmites australis* ssp. *australis*). Wherever invasive plants that respond to burning or cutting by proliferating from root suckers are established, such as black locust (*Robinia pseudoacacia*) and autumn-olive (*Elaeagnus umbellata*), they must be eradicated by localized herbicide application before fire is used. This is true also of Chinese silvergrass, which burns explosively (D. Taylor, personal communication), endangering the safety of burn crew members and posing a risk of escape via clumps of burning leaves lofted into the air.

Most managed disturbances, including prescribed burning, are not expected to place archaeological resources at any significant risk. Salvage surface collection before prescribed burns are generally infeasible because of their great expense (J. T. Sturdevant, personal communication). Experiments have been conducted in several national historical parks to assess the compatibility of prescribed burning, mainly of grasslands (Sayler et al. 1989; Buenger 2004; Sturdevant 2006). Effects on archaeological resources have been negligible. Buffer zones are designated around the most vulnerable artifacts—standing wooden structures—and burning is prohibited there. Grassland fuels seldom burn hot enough to cause damage other than discoloration to small objects of stone, ceramic, bone, shell, metal (including lead), glass and even wood when they are scattered on the ground surface (Sayler et al. 1989; Buenger 2004). Objects covered by as little as 1–2 cm (⅜–¾ inch) of soil are generally unaffected. Charcoal from prescribed burning does not interfere with the dating of archaeological remains (J. T. Sturdevant, personal communication). Managers who oversee prescribed burning in several national historical parks who were contacted for the present study echoed these experimental findings (K. Foote, B. Gorsira, C. Wienk, personal communications). Cultural resource protocols for fire and fire management activities in national parks are under development (National Park Service 2005; J. T. Sturdevant, personal communication).

A dense growth of tall plants is the norm in agriculturally altered soils with excess nutrient availability compared with native soils (see *Soil dynamics*, above). However, vegetation sparse enough to accommodate shorter, shade-intolerant species was the historical norm, at least in patches. The desired patchiness can be achieved by varying disturbance severity and frequency in different parts of the landscape, with some places receiving severe enough disturbance to kill plants and reduce labile soil organic matter. All of the natural disturbance types sustaining grasslands and meadows in the region historically—fire, grazing and browsing, soil scarification, flood or ice scour, and intermittent soil saturation—typically have patchy severity and irregular frequency, keeping some areas but not others from developing a dense growth of tall plants.

The desired mosaic of patch types can be manipulated to enhance aesthetic or interpretive value in particular situations. Certain types of grasslands and meadows will be more appropriate than others for particular interpretive sites, and management could be aimed at achieving and maintaining particular patch types to produce the desired aesthetic or interpretive condition. Patches of different textures, colors and phenologies may be established to highlight edges of historical significance and to some degree mimic the appearance of an eighteenth-century patchwork of fields with various crops, fallow fields and pastures. This may be accomplished and sustained by judiciously varying:

- species composition of planted seed mixes
- seasonal timing of artificial disturbance events (mowing, prescribed grazing or prescribed burning)
- return intervals between artificial disturbance events

Species Augmentation and Translocation

Animals other than birds are particularly vulnerable to climate change because, with the exception of a few long-distance-flying insects and bats, they are unable to cross the wide expanses of inhospitable ground between highly fragmented remnants of habitat. Plants vary in their dispersal modes, but many species' seeds are dispersed mainly within a short distance of the parent plant. Conservation biologists increasingly are considering "assisted colonization," a category of translocation, for species imperiled by the double jeopardy of global warming and habitat fragmentation. Decision frameworks are being developed for determining which species to target and when. According to Hoegh-Guldberg and colleagues (2008, p. 345):

> Previous discussions of conservation responses to climate change have considered assisted colonization as an option, but have stopped short of providing a risk assessment and management framework for how to proceed. Such frameworks could assist in identifying circumstances that require moderate action, such as enhancement of conventional conservation measures, or those that require more extreme action, such as assisted colonization. These frameworks need to be robust to a range of uncertain futures.

The Pennsylvania Biological Survey (www.altoona.psu.edu/pabs) has developed guidelines for assisted migration, reintroduction and augmentation of native populations (T. Maret, personal communication). Those applicable to achieving the desired condition of VAFO grasslands and meadows include:

> The primary reason for a reintroduction project should be the continued long-term survival of the species. Other appropriate reasons include re-establishing a keystone species or restoring historic biodiversity.
>
> Reintroduction programs are fraught with peril and a number of issues should be taken into consideration before a reintroduction project is implemented. Among these are:
>
> - There should be strong evidence that the species will not naturally re-populate the area under consideration for reintroduction
> - The natural history of the species, both at the site of reintroduction and at the … donor site, should be well known.
> - The factors that were responsible for the extirpation of the species at the reintroduction site should be understood and it should be determined that these factors are no longer in play at the reintroduction site.
> - The effects of the reintroduced species on the ecosystem as a whole and species within the system in particular should be carefully assessed both in terms of competition and predation.
> - There should be an analysis to determine the long-term stability of the venue of reintroduction with appropriate plans to protect, enhance and if possible expand the site of reintroduction.
> - The identification of a source area must be carefully researched. The donor site should be selected based on the best possible information regarding genetic and ecological characteristics of the donor population. The donor population should be geographically as close to the reintroduction area as possible and should be subjected to similar climatic regimes to prevent the danger of out-breeding depression.
> - The donor population should be carefully studied prior to removal of any individuals to determine that the removal will not be detrimental to the donor population. Life history stages from the donor population that have the least effect on recruitment should, whenever possible, be used to establish the new population at the reintroduction venue. …
> - During the planning stage of any reintroduction, protocols should be developed for the long-term monitoring of the reintroduced animals [or plants]. Cost for the monitoring should be determined and a funding source for the long-term monitoring identified.

VAFO grasslands and meadows will provide opportunities for assisted colonization of imperiled species, whether they are imperiled by climate change, habitat fragmentation or other causes. Of animal species, most of the candidate species based on current knowledge are butterflies, for instance, the regal fritillary (*Speyeria idalia*), for which a "repatriation" program already exists, coordinated by biologists associated with the Pennsylvania Department of Military and Veterans Affairs, the agency responsible for protection and management of the sole remaining eastern North American population at Fort Indiantown Gap. Among plants, any of the grassland/meadow species of special concern present in the park or recorded historically at or near Valley Forge are candidates for augmentation or reintroduction.

Where remnant populations of rare plants at VAFO have dwindled to such small size that they are in danger of being extirpated if not "rescued," their population numbers may be augmented. The preferred first step is to use plugs or potted plants grown from seed collected from VAFO individuals. Long-term, if this stratagem should fail for any species, the next step would be using plugs or potted plants grown from seed collected from the nearest indigenous populations where the species is still thriving.

Only plants reared from seed collected from remnant, unplanted, native populations in the Greater Piedmont or immediately adjoining ecoregions with similar soils and bedrock geology are appropriate for use in grassland and meadow reclamation in VAFO. In the case of native plants of special conservation concern already present in VAFO grasslands and meadows, it is crucial that they be from seed harvested within the park. For reintroductions of historical species and introductions of potential species, it is appropriate to use seed gathered at the nearest locations for which assurance is relatively high, based on expert opinion, that source plants are not themselves from planted stock but are of genotypes indigenous to the growing site.

More than 25% of the species in Appendices D and E (pp. 207, 239) are available commercially from native plant suppliers in the region and more native grassland/meadow species are becoming available each year. However, the majority of the available plants are not reared from seed collected from native populations located in or adjoining the Greater Piedmont. In many cases, native plant nurseries do not know or are not able to vouch for the provenance of their stock. Wholesale suppliers sometimes are willing to provide assurance of provenance but in other cases may not know whether their stock is of mixed genetic origin because of interbreeding among plants growing close enough together in commercial seed plots to allow cross-pollination.

If seeds of genotypes indigenous to the region are not presently available for a desired species, the best option is custom seed production, using seeds collected in small quantities from remnant, unplanted, native populations to establish production plots. The seed output can then be used to populate larger reclamation areas. Suppliers are increasingly accommodating to restorationists' concerns about provenance and genotype and may undertake custom seed production if the desired quantity and price make the effort worthwhile. Alternatively, consideration may be given to VAFO staff and volunteers collecting seed and establishing production plots within the park. It is vital that care is taken to verify that seed sources are of locally indigenous stock and that caution is used to prevent overcollecting that might endanger the ecological integrity and long-term viability of the sources.

Reducing Soil Nutrient Availability

Another disturbance method worth experimental study in the park's grasslands and meadows is soil organic matter removal. It has been effectively employed in several serpentine grassland restoration projects in southeastern Pennsylvania with consistently favorable results. Removing the top 5–15 cm (2–6 inches) of soil has restored high native herbaceous species diversity in areas where no other method (except burning after small-scale simulated severe drought) was effective (R. E. Latham, unpublished data). Anecdotally, a grassland was discovered recently near VAFO with a high diversity of native grassland/meadow plants, including species of special conservation concern, and almost no cover of nonnative plants despite being surrounded by land where invasive species are dominant (listed under *Miscellaneous* in Table 22, p. 62); it occupies a site where topsoil was removed several decades ago. This method is not suited to areas where archaeological remains lie on or near the surface, but it could be employed in the park's grassland/meadow areas with low archaeological value, or where plowing or earthmoving activity since the eighteenth century has thoroughly mixed the upper soil layers. Soil organic matter removal could be tested in small-scale trials on qualifying sites within the park as part of an adaptive management program.

Soil carbon addition shows some promise as a method for restoring native grassland communities on soils bearing residues of past fertilizer or manure application (Averett et al. 2004; Blumenthal et al. 2003). It has been effective in lowering nutrient availability to plants by serving as an energy source for soil bacteria and fungi, which then tie up large amounts of nitrogen and other nutrients in their own bodies. Reclamation of grassland or meadow on former agricultural land is often impeded by failure to establish a diverse native species assemblage and by interference from nonnative species. High availability of soil nitrogen and other nutrients on such sites favors fast-growing invasive species at the expense of slower-growing native grassland species, which are adapted to, and characteristic of, low-nutrient soils.

Reducing the availability of nitrogen, whose scarcity is the most likely of all nutrients to limit growth in VAFO grasslands and meadows, has been demonstrated to favor natives over nonnative invasives in several grassland reclamation projects. For example, on an abandoned farm field in Ohio (Averett et al. 2004), applying 6 kg m^{-2} (27 tons per acre) of hardwood sawdust on experimental plots caused a 94% reduction in net annual N mineralization, a 27% increase in soil moisture, and no effect on total N or pH, compared with control plots. In the first growing season after amendment, plant mass decreased 34% for native forbs, 67% for native grasses, and 62% for nonnatives but after the second growing season, only nonnatives were significantly affected, with a 40% reduction in mass. Similar results were obtained in an experiment in Minnesota (Blumenthal et al. 2003), where 14 levels of carbon addition were tested—controls (zero C addition) and application of 0.22 to 8.6 kg m^{-2} (1 to 38 tons per acre) of a 6% sucrose-94% sawdust mixture. Soil carbon addition is another method that could be tested in small-scale trials on qualifying sites within the park as part of an adaptive management program.

Reducing Grassland/Meadow Fragmentation

Cutting fencerows and narrow strips of trees between fields is desirable to create much larger fields. Doing so, even if the resulting larger field is sinuous in shape, greatly enhances the attractiveness of grassland and meadow habitat for area-sensitive grassland-nesting species (O'Leary and Nyberg 2000). Area-sensitive birds do not use the edges of fields as much as the interior area, an effect that is measurable as far as 50 m (160 feet) from wooded edges or fencerows (Winter et al. 2000; Bollinger and Gavin 2004). Thus, when fencerows and narrow wooded strips between existing fields are removed, the increase in the area of preferred nesting habitat can be much greater than the area of brush or woods that is cut.

There are trade-offs in fencerow removal; some fencerows and narrow strips of trees between fields may be dispersal and foraging corridors for wildlife, including small mammals and nocturnal predators. However, those same small mammals and nocturnal predators are among the chief nest predators of ground-nesting birds, and edges are where brood parasitism rates by brown-headed cowbirds are highest. Most, if not all, wildlife species that depend on fencerows and tree-lines between agricultural fields are secure in Pennsylvania, whereas grassland-interior birds are of high conservation concern and most are undergoing rapid population declines. Weighing costs and benefits to wildlife habitat and biodiversity favors fencerow removal on public lands.

Native Species Prioritization

Prioritizing native plant and animal species for restoration and management (including translocation if appropriate) may follow this rough guideline to assigning rank order, from highest to lowest priority:

1. Species of special conservation concern present in the park (and any other species on which they depend, such as host plants for specialist herbivores)

2. Species of special conservation concern historically present at Valley Forge but not seen recently

3. Globally rare species of special conservation concern present elsewhere in the Greater Piedmont for which habitat exists or is appropriate for reclamation in the park

4. Species imperiled by global climate change for which habitat exists or is appropriate for reclamation in the park

5. Other species of special conservation concern present elsewhere in the Greater Piedmont for which habitat exists or is appropriate for reclamation in the park

6. Uncommon species present elsewhere in the Greater Piedmont for which habitat exists or is appropriate for reclamation in the park

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