Keystone Grasslands

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Executive summary

Grasslands, meadows, and savannas (GMS) share two distinctions with wetlands: they are crucial for biodiversity conservation out of proportion to their small total area and they declined severely during the twentieth century. Recognition of their importance lags behind that of wetlands, but is making steady gains. In Pennsylvania, GMS are identified as a high priority for restoration, reclamation, and management by the state's Wildlife Action Plan. Worldwide, temperate grasslands, savannas, and shrublands are of acute conservation concern. The ratio of converted (developed) to protected land is ten to one in, five times higher than even the beleaguered tropical rainforest. Only 4.6% of the land in temperate grassland, savanna and shrubland has been protected to date while 45.8% has already been destroyed. The figures are even more dismal for Pennsylvania, where native GMS have been under extreme pressure for more than 300 years and most were converted long ago to agricultural, residential, commercial, and other uses.

Twentieth-century changes in agricultural practices resulted in dramatic declines of most grassland birds and other grassland-dependent wildlife in Pennsylvania and other eastern states. The remaining hotspots for grassland plant species, as well as for the butterflies, moths, and other insects that are dependent on them, are far less extensive than even the declining habitats for grassland birds.

The Pennsylvania Department of Conservation and Natural Resources and the Pennsylvania Game Commission are two of the largest landowners in the Commonwealth, with a combined total of 3.8 million acres in state forests, state parks, and state game lands. A very small fraction of these lands is already in grassland, meadow, and savanna communities dominated by native plant and animal species but a great deal more is in open areas dominated by non-native species, well suited for restoration or reclamation of native GMS. This study was undertaken to address the question: Where and how can functional native grasslands be restored or reclaimed on Commonwealth lands? We sought to:

- identify potential native grassland/meadow reclamation sites on state-owned land;
- identify remnants of historical native grasslands, meadows, and savannas statewide, including those on state-owned land, to serve as models for native GMS reclamation and sources of local native genotypes; and
- identify and evaluate the plant and wildlife species native to grasslands, meadows, and savannas in Pennsylvania that have significance for restoration and reclamation.

Because the most dramatic declines in GMS habitats in Pennsylvania have been in the Great Valley and Piedmont regions, we included all 24 state parks and 38 state game lands in the 15 counties south and east of Blue Mountain as well as 15 state parks in other parts of the state in our analysis. Using interpretation of false-color infrared satellite imagery, maps, and information from pasts visits and consultation with colleagues, we identified areas potentially suited to native grassland/meadow reclamation in 35 parks and game lands, totaling approximately 14,790 acres or about 23 square miles.

To identify reference sites to serve as models for reclamation and sources of native genotypes, we compiled locations and vascular plant species lists for present-day grasslands, meadows, and savannas across the state that are dominated by native herbaceous species but where native species were never planted, and that are long-lived. The total area of the 64 sites identified is roughly 2,100 acres. Many of these sites are from less than one acre to just a few times that size; the largest is a "new" (post-European-settlement) area of approximately 900 acres. The sites with the greatest concentrations of rare species, mostly remnants of larger GMS pre-dating European settlement, account for about 20% of the area of all extant sites in this survey, perhaps 400 acres across the state. A few of these exceedingly rare and valuable (and, for the most part, still declining) remnants of historical GMS are on Commonwealth lands. They provide unique opportunities for the Department of Conservation and Natural Resources and the Game Commission to protect, restore, and manage irreplaceable reference sites and the rare, declining local genetic stock of the vascular plant species that are most valuable for reclamation.

To compile a comprehensive list of the native vascular plant species characterizing GMS in Pennsylvania, we made a progressive series of deletions from the 2,981 vascular plant taxa currently listed in the Pennsylvania Flora Project database[1] as occurring in the wild. In addition to non-natives, we excluded taxa that are aquatic or semi-aquatic, hybrids, and those whose habitat description lacks any of the keyword strings *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. Native vascular plants that characteristically inhabit Pennsylvania's grasslands, meadows, and savannas, including ephemeral, early-successional assemblages as well as persistent GMS communities, number 862. Of these, 765 are herbaceous and 97 are woody.

GMS species are disproportionately represented among vascular plant species of special conservation concern: 112 (38%) of the state-endangered species, 35 (41%) of the state-threatened species, and 38 (35%) of the species that have already been extirpated from Pennsylvania are characteristic of grasslands, meadows, and savannas. These percentages are about double the 19.5% of the state's land currently estimated to be in GMS cover and are vastly disproportionate to the 1% to 3% of the land within Pennsylvania's borders estimated from historical sources to have been in GMS vegetation around the time of European settlement.

The palette of native plants that may be used in reclamation plantings consists of at least 60 grasses, 80 other graminoids (sedges and rushes), and nearly 400 forbs. Of the native grass species suggested for reclamation use, 32 are cool-season and 28 are warm-season. These figures do not include plants on the state's list of species of special concern; many of the 237 GMS plant species of special concern are also appropriate for some restoration and reclamation projects, but only where a science-based recovery plan or a carefully considered exemption from this requirement has been formulated.

At present, less than one-fifth of the native herbaceous species (but including more than one-quarter of the grasses) most qualified for GMS reclamation planting are commercially available as seeds of native Mid-Atlantic genotypes. Reclamation practitioners who hope to attain levels of native plant species richness and wildlife habitat diversity comparable to historical and remnant native GMS stands will need to obtain seeds by wild-collecting as well as by purchase. Of the plants suggested for GMS reclamation use, those commercially available include at least 7 of the

[1] Maintained at the Morris Arboretum, University of Pennsylvania (www.paflora.org).

native cool-season grasses, 10 of the warm-season grasses, 14 of the other graminoids, and 65 of the forbs.

Pennsylvania's breeding bird fauna includes 15 species that are referred to as grassland-obligate or grassland-interior species, that is, in order to nest and successfully rear young they need access to large grasslands, meadows, or savannas 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 declining bird, mammal, and reptile species depend on native GMS 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 GMS because their larvae are specialist feeders on hosts that are native to these habitats. Even higher percentages use GMS as adults as a source of nectar.

Grassland birds evolved in native grasslands characterized by high species richness of grasses and perennial forbs and patchiness in such environmental factors as litter depth and amount of bare ground, resulting from grazing, fires, and other disturbance. They have highest preference for, and achieve greatest survival and reproduction in, existing grasslands with comparable structural and species composition. Grassland bird 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. A large, contiguous habitat area is critical for all grassland-obligate species, and density, diversity, and offspring survival increase with the size of a habitat "island." In the Mid-Atlantic region, it takes a minimum of 100 to 250 acres of contiguous GMS to support multiple grassland-obligate bird species, although patches as small as 12 to 25 acres sometimes support small numbers of a single species.

In converting existing cultivated fields, old fields, and other open habitats in state parks and state game lands to native GMS, cutting fencerows and narrow strips of trees between fields is recommended to create much larger fields. Because area-sensitive birds do not use the edges of fields as much as the interior area, the increase in the area of preferred nesting habitat can be a good deal greater than the area of fencerows and narrow wooded strips that is cut.

When time, funds, and land are allocated to native GMS reclamation in the hopes of attracting nesting pairs of grassland-obligate 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.

A primary goal of GMS reclamation on state park and state game lands should be to provide *source* habitats, that is, large areas of contiguous, high-quality habitat in which the population growth rates of a variety of grassland-obligate bird species are positive. A worthy secondary goal would be to expand the supply of *sink* habitats, lower-quality habitat areas that are nonetheless important to help sustain high overall population numbers and genetic diversity. 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.

Promoting a high diversity of vascular plant species and habitat structure is a major key to benefiting moths and butterflies in GMS reclamation and management. The specific host plants of rare lepidopterans known to occur in the regions surrounding GMS reclamation projects should be special targets of the planting, monitoring, and management programs at all such sites in state parks and state game lands.

Diverse native GMS with a mix of native cool-season grasses, warm-season grasses, and forbs almost certainly support a higher biomass and diversity of wildlife than the mostly artificial environments that make up the majority of GMS or GMS-like habitats today, including annual crop fields, hayfields, pastures, old fields dominated by invasive non-native plants, reclaimed strip mines, and utility rights-of-way. Insects are vital links in many of the food chains that make up the trophic web in terrestrial ecosystems and many insects are specialist feeders on a narrow range of plant species. A higher species richness of native plants entails a higher insect diversity and can support a higher insect biomass in a given area of land. Non-native plants are eaten to a far lesser degree than native plants by insects and other herbivores (the relative lack of consumers is part of the reason why some non-native plant species are invasive), and so less of the biomass of non-native plants is converted, via the food chains that make up the trophic web, into animal biomass. Insects are the richest source of fats and protein for many small vertebrates, which in turn are food for many larger vertebrates. Higher plant species richness also means higher structural diversity of habitat for wildlife, which contributes to higher animal diversity and population numbers within a given area. It is axiomatic that rich mixtures of native species, such as we see today mainly in the small, rare, historical GMS remnants, provided native wildlife species exactly what they needed for millions of years.

A few widespread misconceptions about GMS can be dispelled based on the available evidence. For instance, not all native grasses are warm-season grasses and vice-versa; there are actually more species of *native* cool-season grasses than the number of commonly planted non-native grasses. Likewise, a monoculture — even a field of native warm-season grasses — in reality does *not* constitute good wildlife habitat. Converting state park lands and portions of state game lands that are now devoted to annual crops, non-native cool-season hay species, or warm-season grass monocultures to species-rich, structurally diverse native GMS communities should be a high priority if high wildlife diversity as well as high game production is the goal.

A regional or statewide GMS restoration/reclamation program should begin with a detailed assessment and prioritization of available sites. Although restoration is perhaps more urgent than reclamation from a conservation perspective, appropriate sites for restoration (those with existing native GMS remnants) are more limited and the potential GMS area is often relatively small. A regional or statewide GMS restoration/reclamation plan should take into account the need both for plant community restoration and for GMS reclamation and grassland-obligate bird recovery.

Selection of plant species for reclamation requires matching the soil parent-material preferences of native GMS plant species to the site, filtering the resulting list to yield those whose seeds are available from commercial suppliers or from sites available for wild-collecting, and further winnowing to those species that are appropriate for the local soil moisture regime. The provenance of the plants should be within or nearby Pennsylvania and preferably in the same ecoregion as the site to be planted. Because certain native grass species tend to be aggressive and crowd out other species, it is best to mass forb plantings and separate them spatially from the grass plantings. This type of patchiness is common in nature and should be imitated to the extent possible in restoration and reclamation.

Once grasslands, meadows, or savannas are established, maintenance is required to keep them from becoming shrubland or woodland, to halt the spread of invasive, non-native species, to maintain a mix of patches of different ages and species composition, and sometimes to keep native grasses from crowding out other species. The preferred method is prescribed burning, but grazing, spot-application of herbicides, winter mowing, and mechanical removal of the top layer of soil organic matter all have a place. Mowing is not ecologically equivalent to burning or grazing, in part because it fails to create areas of bare soil, which are a requirement for some wildlife species and as sites for seed germination and colonization for less-competitive plant species. Patches of bare soil commonly develop in prescribed fire "hot spots" and in places where grazers uproot, trample, or wallow. Winter mowing can be used in special circumstances, but mown material should be collected and removed. Prescribed burning should be rotated among patches in different years, with no more than one-fifth to one-third of a field or cluster of fields burned in any one year, to provide for quick recovery of local populations of wildlife that cannot escape the flames.

In planning for GMS restoration or reclamation, it should be very clear that failure is possible and beyond the control of even an excellent practitioner. Such temporary setbacks should be programmed into the operating plan for any grassland restoration/reclamation effort. The need for contingencies must be clear in the plan. A detailed, individual plan for each site should be drafted and vetted before proceeding with restoration or reclamation. It is recommended that a regional or statewide restoration/reclamation plan start with a few representative site types and that detailed plans, with contingencies, be written for each site.

Introduction

Grasslands, meadows, and savannas (GMS) share two distinctions with wetlands: they are crucial for biodiversity conservation out of proportion to their small total area and they declined severely during the twentieth century. Recognition of their importance lags behind that of wetlands, but is making steady gains. In Pennsylvania, GMS are identified as a high priority for restoration, reclamation, and management by the state's Wildlife Action Plan, or PA-WAP (Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2005). Scientists conducting a global study of total areas of habitat converted or destroyed compared with habitat protected in all major ecosystem categories showed a bleak picture for GMS worldwide (Hoekstra et al. 2004). Of all ecosystem types evaluated, temperate grassland is in the direst straits. For temperate grassland, savanna and shrubland together, the ratio of converted to protected land is ten to one, five times higher than even the beleaguered tropical rainforest. Only 4.6% of the land in temperate grassland, savanna and shrubland has been protected to date while 45.8% 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.

Grasslands, meadows, and savannas are plant communities dominated by herbaceous plants that do not have standing water or fully saturated soil for more than a few days per year at most and are mowed, if at all, no more than once a year. Even though there are no widely accepted quantitative definitions for these broad ecosystem categories, for this report GMS are defined roughly as follows. ***Grasslands*** are dominated by grasses (more than 50% cover) and have few or no trees (less than 5% cover). ***Meadows*** are dominated by forbs (non-grasses; more than 50% cover) with few or no trees. ***Savannas*** are dominated by either grasses or forbs with sparse, scattered trees or tall shrubs (between 5% and 25% canopy cover). Any GMS community may have a significant low shrub component, as long as herbaceous plant cover is at least 50%.

Several other distinctions require explanation at the outset, namely, the differences among restoration, reclamation, and maintenance, and the continuum between successional GMS and persistent GMS. "Ecological restoration is 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). ***Restoration***, as we use the term in this report, applies only to remnants of long-persisting historical GMS that have been degraded as the direct or indirect result of human activities. Such remnants are exceedingly rare in Pennsylvania but they do exist, in a few cases on state lands.

Reclamation involves similar activities, but on land that probably did not support GMS historically. "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). The best management practices for restoration and reclamation are similar, but there are important differences. For instance, GMS restoration usually involves the recovery of endangered, threatened, or rare plant species, whereas reclamation projects should avoid using seed of these species unless they are part of a scientifically sound, carefully planned reintroduction and recovery program.

Maintenance is an ongoing, permanent necessity for nearly all GMS in Pennsylvania, whether they are persistent remnants of historical GMS or the result of restoration or reclamation. GMS species are distinguished from others by their high tolerance for disturbance and generally low tolerance for the shade beneath a forest canopy. Virtually all GMS occurrences in the state are the result of disturbance. Given the prevailing soils and current climate of Pennsylvania, a prolonged lack of disturbance eventually leads to forest cover. Maintenance of native grasslands, meadows, and savannas consists of mimicking key aspects of the disturbances that maintained such plant communities in the past, either for the roughly 13,000 years of human occupation before European settlement or during the many interglacial periods when the climate was similar to today's, totaling several hundred thousand years over the past two million years.

A particular grassland, meadow, or savanna may fall anywhere along a continuum of stability between maintenance disturbances, from ***successional (short-lived)*** to ***persistent (long-lived)***. This is a key concept for successful management. Anything that slows the growth of plant life can prolong the period during which a given GMS can persist between maintenance disturbances, with its structure and species composition intact. Certain soil conditions slow plant growth, including low soil nutrient levels, a droughty moisture regime, shallow soil over bedrock, a soil hardpan, or unusual bedrock chemistry. Micro- or mesoclimatic conditions also can slow plant growth; examples are frost-pocket conditions, chronic heat stress, or high wind exposure. Furthermore, dominant GMS plant species can impede invasion by forest tree seedlings, for instance, by creating dense shade, increasing soil acidity, decreasing nutrient availability by inhibiting decomposition, providing insulation that slows soil warming in spring, or competing more efficiently for water and nutrients (Berkowitz et al. 1995; Bramble et al. 1996).

Open areas dominated by non-native species, often with extremely low species diversity and little value as wildlife habitat, cover a much larger area in the state than GMS dominated by diverse mixtures of native plants. Recent estimates categorize 11.5% of Pennsylvania's land cover as cropland[1] and 19.5% in categories that include grassland, meadow, and savanna cover but also include other cover types with similar signatures in satellite images, such as pasture and regenerating forest[2] (Myers et al. 2000). The amount of land in GMS dominated by native species is unknown, but may account for less than 1% of the state's land area (R. E. Latham, unpublished data).

Twentieth-century changes in agricultural practices resulted in dramatic declines of most grassland birds and other grassland-dependent wildlife in Pennsylvania and other eastern states (Bollinger and Gavin 1992). Hayfields were mowed earlier in the summer, before the end of the nesting season. There was a gradual switchover from cropland rotation with long fallow periods to more intensive rotation among crops. Pesticide use was a contributing factor, in part from toxic effects on adults, juveniles, and eggs but more importantly by reducing the supply of insect prey essential for supplying fats, protein, and calories to fast-growing young birds. Besides the changes in the way farmers managed their land, much farmland was abandoned to revert to thicket and forest, or sold off for residential or commercial development.

In the latter half of the twentieth century, the most productive habitats for birds that breed only in large, unbroken tracts of grassland switched over from fallow farm fields to large, grassy former

[1] "Annual herbaceous (row crops, grain crops, exposed mineral soil)" (Myers et al. 2000)

[2] The sum of "woody transitional (5% < cover of woody plant foliage < 40%), also shrubland or forest regeneration" and "perennial herbaceous (grasslands, pasture, forage, old fields < 5% shrubs)" (Myers et al. 2000)

strip mines, mainly in the west-central part of the state (Mattice et al 2005). Reclamation of these surface mines involved planting non-native cool-season grasses and legumes before the 1977 Surface Mining and Reclamation Act, which required that the surface of mined sites be planted with the cover type that existed prior to mining, most often trees. However, tree establishment had a poor success rate on many sites because of poor soils and competition from planted grasses and legumes (Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2005).

The remaining hotspots for grassland plant species, as well as for the butterflies, moths, and other insects that are dependent on them, are far less extensive than even the declining habitats for grassland birds. The most valuable are the scattered remnants of historical grasslands. They include:

- serpentine grasslands/savannas in the Piedmont uplands of southeastern Pennsylvania;
- xeric limestone prairies in the Appalachian valleys;
- hairgrass savannas on Appalachian ridge tops;
- mesic calcareous meadows in the Pittsburgh Low Plateau region;
- mesic diabase meadows in the Piedmont Triassic lowlands;
- sand-plain grasslands, beach-grass dunes, and black oak savannas at and near the shores of Lake Erie;
- coastal-plain sandy meadows in the lower Delaware River valley; and
- riverside meadows/grasslands along the Susquehanna, Delaware, Allegheny, Youghiogheny, and other major streams.

Some of the historical GMS remnants have exceptionally high native plant species richness. Nearly all include significant clusters of endangered, threatened, and rare vascular plants and animals (mainly insects). Unfortunately, these remnants have declined from an estimated 230 to 240 square miles around the time of European settlement (0.5% of the state's total land area) to less than 1 square mile today, a 99.6% decline, which continues and is even accelerating at many sites (R. E. Latham, unpublished data). These remnant native grasslands, meadows, and savannas are irreplaceable resources of great value for:

- protection and stewardship of rare plant communities and roughly 300 rare plant and animal species;
- defining models of species composition for restoration of remnant grasslands;
- serving as templates for the creation of new native grasslands that will favor success in establishment and enhancement of wildlife habitat under particular sets of soil and microclimatic conditions; and
- collecting seeds of local genotypes for use in restoration and reclamation.

There are also a few sites where GMS of more recent origin are maintained, where non-local genotypes of native species were never planted and non-native species are scarce. The largest such site is the training corridor at Fort Indiantown Gap, owned and managed by the Pennsylvania Department of Military and Veterans Affairs (Figure 1). Portions of this high-quality 900-acre grassland complex provide habitat for the only known population of the critically endangered eastern regal fritillary (*Speyeria idalia idalia*). Another large site in this category is Valley Forge National Historical Park, with about 700 acres of grasslands altogether, although native plant species dominate only a fraction of the total. Among a number of smaller sites are grassy heaths maintained by wildfire and white-tailed deer browsing, scattered throughout the state.

The Pennsylvania Department of Conservation and Natural Resources and the Pennsylvania Game Commission are two of the largest landowners in the Commonwealth, with 2.1 million acres in state forests, 283,000 acres in state parks, and 1.4 million acres in state game lands. A very small fraction of these lands is already in grassland, meadow, and savanna communities dominated by native plant and animal species but a great deal more is in open areas dominated by non-native species, well suited for restoration or reclamation of native GMS. The purpose of this study is to address the question: Where and how can functional native grasslands be restored or reclaimed on Commonwealth lands? Specific objectives are:

- to identify potential native grassland/meadow reclamation sites on state-owned land;
- to identify remnants of historical native grasslands, meadows, and savannas statewide, including those on state-owned land, to serve as models for native GMS reclamation and sources of local native genotypes; and
- to identify and evaluate the plant and wildlife species native to grasslands, meadows, and savannas in Pennsylvania that have significance for restoration and reclamation.

Figure 1. Part of the 900-acre native grassland-meadow complex at Fort Indiantown Gap, managed by the Pennsylvania Department of Military and Veterans Affairs in part to provide habitat for the only known population of the critically endangered eastern regal fritillary (*Speyeria idalia idalia*).

Methods

Identifying potential native grassland/meadow reclamation sites on state-owned land in Pennsylvania

We restricted our survey to state parks and state game lands. Because the most dramatic declines in grassland, meadow, and savanna habitats have been in the Great Valley and Piedmont regions (McWilliams and Brauning 2000), we included all state parks and state game lands in the 15 counties south and east of Blue Mountain (Kittatinny Ridge). We also investigated other sites, mainly state parks, in the rest of the state that we judged most likely to have potential grassland/meadow reclamation sites.

Our survey was based primarily on interpretation of false-color infrared satellite imagery taken in 2004 from the U.S. Department of Agriculture's National Agriculture Imagery Program (NAIP). For some sites, we also used grayscale imagery taken in 1997-2001 in the U.S. Geological Survey's digital orthophoto quarter quadrangle mosaics (DOQQ). Data on bedrock geology came from Berg et al. (1980), Berg and Dodge (1981), and Geyer and Wilshusen (1982). Additional information came from maps (U.S. Geological Survey, Pennsylvania Department of Conservation and Natural Resources, Pennsylvania Game Commission), past visits to some of the sites by R. Latham, and personal communication with Dr. Ann Rhoads.

Identifying remnants of historical native grasslands, meadows, and savannas in Pennsylvania

One of us (R. Latham) compiled locations and vascular plant species lists for present-day native GMS in Pennsylvania that meet a stringent set of criteria: (1) They are dominated by native herbaceous species. (2) They show no evidence that native species on the site were ever planted. (3) They appear to be relatively persistent, that is, influenced by conditions and processes that slow or prevent invasion by woody plants. The information came from nearly 25 years of fieldwork, from colleagues with similar levels of field experience in the state, including botanists and ecologists from the Pennsylvania Natural Heritage Program at the Western Pennsylvania Conservancy, and from others with a particular interest in individual sites or groups of sites. Contributors included Dr. Ann Rhoads, Dr. Larry Klotz, and Dr. Jim Bissell (see Acknowledgments for institutional affiliations).

One of the premises on which this analysis is based is that an exceptional diversity of GMS plants or a cluster of rare GMS plant species is a good indicator of a grassland, meadow, or savanna's longevity. We have little direct evidence farther back than the earliest botanical records in the mid-1800s, but high species diversity and multiple occurrences of rare species are circumstantial evidence that a site has supported non-forest vegetation for centuries or thousands of years (Latham 2003). Grasslands and meadows in the Mid-Atlantic region most often are dominated by common, opportunistic, early-successional plants, a category that includes many of the most aggressive, non-native invaders as well as many common, native herbaceous species, but few if any rare native species. Nonetheless, some of the region's globally rare species and many regionally rare, disjunct, and edge-of-range species are plants with high fidelity to GMS, and some GMS harbor clusters of rare plant taxa. These observations pose a conundrum; the longevity of these community occurrences seems to be the key.

Because grasslands, meadows, and savannas tend to be isolated and small in the Mid-Atlantic region and dispersal of rare plants is further limited by the sparseness of propagule-exporting populations, multiple rare species are likely to accumulate and persist only where a GMS occurrence is stable over a long time period. Certain conditions slow succession or repeatedly set it back, including soils at the two extremes of the moisture gradient, very shallow soils, and frequent fire, flooding, or ice-scour. However, slowed succession is not the whole story. Many plant species with high fidelity to long-lived GMS are virtually never seen in typical early-successional habitats such as abandoned farm fields, forest blowdowns, or clearcuts. They cannot be classified as early-successional plants because they do not inhabit true early-successional habitats. Assemblages dominated by native plant species that are restricted, or nearly so, to GMS are the focus of this study. They are termed *persistent* grasslands, meadows, and savannas, although it is not always necessary that they have existed for centuries at exactly the same spot to fall into this category. A localized cluster of grassland, meadow, or savanna patches interspersed with thicket or forest patches in a slowly shifting mosaic can also be termed persistent.

Identifying the native vascular plant species characteristic of grasslands, meadows, and savannas in Pennsylvania

The "palette" of species for restoration of historical GMS and reclamation of degraded land to new GMS consists of the set of native species most often, or exclusively, found in grasslands, meadows, and savannas in various parts of Pennsylvania. To identify all of the native GMS vascular plant species, we conducted a progressive series of deletions from the 2,981 vascular plant taxa currently listed in the Pennsylvania Flora Project database as occurring in the wild in the state (updated September 2007). First we deleted taxa that are non-native, aquatic or semi-aquatic, recognized hybrids, and those that do not include any of the keyword strings *barren, clearing, field, grassy, meadow, open/opening, roadside, pasture, serpentine,* or *shore*. Of the remaining taxa, we deleted those whose habitat is mainly open woods, wooded swamps, peatlands, muddy shores, or tidal marshes.

Identifying the rare butterfly and moth species native to grasslands, meadows, and savannas in Pennsylvania

We sought to identify the known food plants for larvae and habitat preferences of the entire roster of butterfly and moth species that are tracked, or proposed for tracking, by the Pennsylvania Natural Heritage Program because of their rarity or suspected rarity, mainly drawing on the rich variety of web-based sources of information on Lepidoptera in the United States. Currently, a total of 66 butterfly species and 92 moth species are tracked statewide; an additional 25 moth species have been proposed for tracking (J. E. Rawlins, personal communication, 2007).

Results

Potential native grassland/meadow reclamation sites on state-owned land in Pennsylvania

We examined 24 state parks and 38 state game lands in the 15 counties south and east of Blue Mountain (Kittatinny Ridge) and 15 state parks elsewhere in the state. Of the 77 sites, we identified 35 with significant areas potentially suited to native grassland/meadow reclamation, totaling approximately 14,790 acres or about 23 square miles (Figure 2 and Tables 1 and 2; see Appendix A for details on our findings for each site).

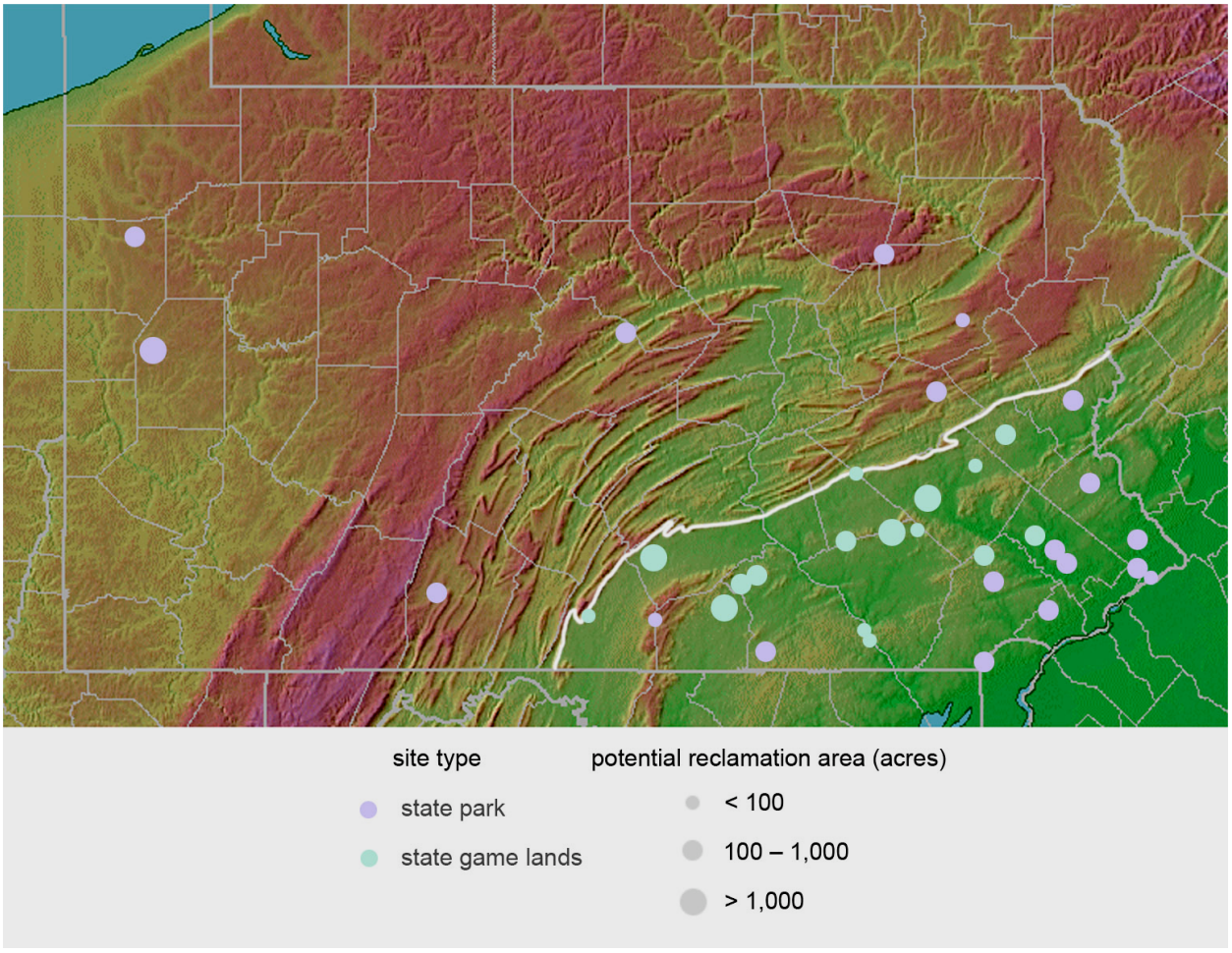

Figure 2. Potential native grassland/meadow reclamation sites identified in state parks and state game lands. Blue Mountain (Kittatinny Ridge) is highlighted. The symbols reflect relative sizes and are not to scale; the symbol size hierarchy on this map is the same as that used in Figure 3.

Table 1. Per-county estimated acreage of potential grassland/meadow reclamation areas in state parks and state game lands.

county/ies south and east of Blue Mountain	acres	sites
Berks	1,855	2
Lancaster & Lebanon	1,860	4
Montgomery	1,600	3
Bucks	1,505	3
Franklin & Adams	1,415	3
Cumberland	1,165	1
Chester	1,200	3
York	940	5
Lehigh	425	1
Delaware	200	1
Northampton	190	1
Philadelphia	125	1
subtotal	12,480	28
county/ies elsewhere in the state	**acres**	**sites**
Butler	1,060	1
Sullivan & Luzerne	455	2
Centre	290	1
Bedford	195	1
Mercer	180	1
Schuylkill	130	1
grand total	14,790	35

Table 2. Per-site estimated acreage of potential grassland/meadow reclamation areas in state parks and state game lands (see Appendix A for details on each site).

site name	acres	county/ies
SGL 280	1,785	Berks
SGL 182	70	Berks
SGL 46	1,585	Lancaster & Lebanon
SGL 145	145	Lebanon
SGL 220	70	Lancaster
SGL 80	60	Lebanon
Evansburg SP	755	Montgomery
Norristown Farm Park SP	570	Montgomery
SGL 234	275	Montgomery
SGL 249	1,265	Adams
SGL 235	80	Franklin
Caledonia SP	70	Franklin & Adams
SGL 169	1,165	Cumberland
White Clay Creek SP	465	Chester
Marsh Creek SP	415	Chester
SGL 43	320	Chester
Tyler SP	850	Bucks
Nockamixon SP	590	Bucks
Neshaminy SP	65	Bucks
SGL 243	350	York
SGL 242	290	York
Codorus SP	165	York
SGL 83	70	York
SGL 181	65	York
SGL 205	425	Lehigh
Ridley Creek SP	200	Delaware
Jacobsburg SP	190	Northampton
Benjamin Rush SP	125	Philadelphia
Moraine SP	1,060	Butler
Ricketts Glen SP	375	Sullivan & Luzerne
Nescopeck SP	80	Luzerne
Bald Eagle SP	290	Centre
Shawnee SP	195	Bedford
M. K. Goddard SP	180	Mercer
Tuscarora SP	130	Schuylkill

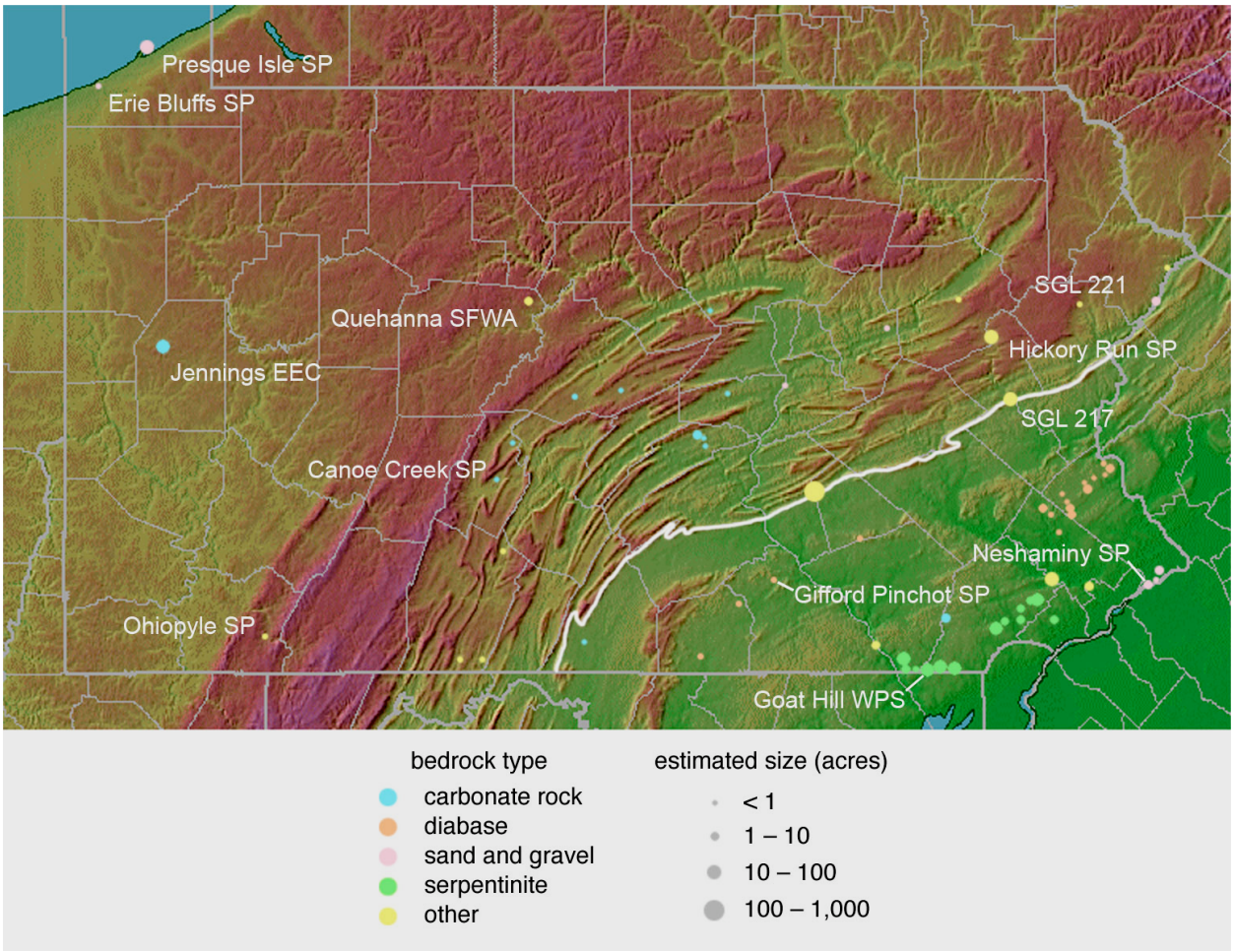

Figure 3. Present-day native grasslands, meadows, and savannas that are dominated by native herbaceous species but where native species were never planted, and that are long-lived (most are remnants of pre-European-settlement plant communities). State parks and state game lands that include occurrences are labeled. Blue Mountain (Kittatinny Ridge) is highlighted. The symbols reflect relative sizes and are not to scale; the symbol size hierarchy on this map is the same as that used in Figure 2.

Remnants of historical native grasslands, meadows, and savannas in Pennsylvania

The survey identified 64 sites of extant native GMS that meet the criteria for inclusion (Figure 3). Among them are as many as 27 remnants of approximately 200 historical GMS sites in Pennsylvania revealed in eyewitness accounts and herbarium records compiled for another study (R. E. Latham, unpublished data). The survey of extant native grasslands and meadows uncovered at least 28 additional sites not detected in the historical analyses, even though several that have clusters of rare or endemic species presumably have existed at or near their current locations for a long time. The remainder are assumed to be "new," that is, of post-European-settlement origin. Most of the 64 present-day native grasslands and meadows are in three physiographic sections: Appalachian Mountain (18 sites), Gettysburg-Newark Lowland (17), and Piedmont Upland (17). The main bedrock types represented are diabase (18 sites), carbonate rock (13), and serpentinite (13).

Many of these sites are from a small fraction of an acre to just a few acres. Among the long-persistent sites, the largest acreage belongs to the serpentine grasslands/savannas of the Piedmont Upland, 13 sites estimated to total approximately 220 acres. The largest single native grassland-meadow complex is one of the "new" sites — the training corridor at Fort Indiantown Gap. Most of its several grassland patches, totaling approximately 900 acres, have been managed since the mid-1990s by the Nature Conservancy and the Pennsylvania Department of Military and Veterans Affairs as habitat for the only known surviving population of the eastern regal fritillary (*Speyeria idalia idalia*). The total area of the 64 sites identified so far, by very rough estimate, is perhaps 2,100 acres. The sites with the fewest rare species, and thus likely to be of recent origin, tend to be large and thus make a disproportional contribution to the total. It is likely that there are other, similar sites not found in this survey.

The sites with the greatest concentrations of rare species, thus probably remnants of very old GMS clusters, account for about 20% of the area of all extant native GMS sites in this survey, perhaps 400 acres across the entire state. A few of these exceedingly rare and valuable (and, for the most part, still declining) remnants of historical GMS are on Commonwealth lands (Table 3 and Figures 3 and 4).

Table 3. Known remnants of historical native grasslands, meadows, and savannas on state-owned land in Pennsylvania.

community description	approx. acres	site (county)
hairgrass ridge-top savanna[1]	~70?	State Game Land 217 (Carbon)
beach-grass dunes[2]	24	Presque Isle State Park (Erie)
dry sand plain[2]	17	Presque Isle State Park (Erie)
palustrine sand plain[2]	5	Presque Isle State Park (Erie)
serpentine grassland/savanna	~15?	Goat Hill Wild Plant Sanctuary (Chester)
mesic calcareous meadow	~12?	Jennings Environmental Education Center (Butler)
coastal-plain sandy meadow	< 10?	Neshaminy State Park (Bucks)
wild-ungulate "pasture"	< 10?	Quehanna State Forest Wild Area
hairgrass ridge-top savanna	< 3?	State Game Land 221 (Monroe)
riverside meadow/grassland	< 1?	Ohiopyle State Park (Fayette)
mesic diabase meadow	< 0.5?	Gifford Pinchot State Park (York)
xeric limestone prairie[3]	< 0.05	Canoe Creek State Park (Blair)
black oak savanna	< 0.05	Erie Bluffs State Park (Erie)

[1] Small fractions of the savanna are on National Park Service and Lehigh Gap Wildlife Refuge lands.
[2] Source for acreage: J. K. Bissell, personal communication (2005).
[3] Source for acreage: Laughlin and Uhl (2003).

Figure 4. Remnant historical grasslands, meadows, and savannas on Commonwealth lands provide unique opportunities to protect, restore and manage irreplaceable reference sites and rare, declining local genetic stock of many vascular plant species that are valuable for reclamation. A (above): State Game Lands 217 (Carbon County); B (below): Presque Isle State Park (Erie County).

Native vascular plant species characteristic of grasslands, meadows, and savannas in Pennsylvania

Native vascular plants that characteristically inhabit Pennsylvania grasslands, meadows, and savannas, including ephemeral, early-successional assemblages as well as persistent GMS communities, number 862. Of these, 765 are herbaceous (Appendices B and D) and 97 are woody (Appendices C and D). Of the herbaceous plants, the habitat descriptions of 336 include the keyword *woods*, which leaves 429 native herbaceous plants classified in this report as wholly or mostly restricted in Pennsylvania to grasslands, meadows, and savannas (identified in Appendices B and D).

Among the 765 herbaceous species, 69% have been classified by their wetland status in the region (summarized in Table 4, part A). In the broadest categories, 35% grow mainly in uplands, 20% mainly in mesic habitats, and 45% mainly in wetlands. The corresponding percentages for the subset that are wholly or mostly restricted in Pennsylvania to grasslands, meadows, and savannas are 75% classified (Table 6, part A), and of these, habitats for 30% are mainly upland, for 19% mainly mesic, and for 51% mainly wetland.

Of the 765 herbaceous species, 92 are grasses, 125 are other graminoids (sedges and rushes), and 548 are forbs (herbaceous plants in all other families). Those that do not have official state status (endangered, threatened, rare, extirpated, or tentatively undetermined and under study) and therefore may be used in reclamation plantings without need for a science-based recovery plan or a carefully considered exemption from this need, number 60 grasses, 80 other graminoids, and 388 forbs. Of the total number of grasses, 49 species have only the C_3 photosynthetic pathway (cool-season grasses) and 43 also have C_4 photosynthesis (warm-season grasses). Grasses on the GMS list without official state status consist of 32 cool-season and 28 warm-season species. In some restoration and reclamation projects it is appropriate to use many of the 237 GMS plant species of special concern, but only after a science-based recovery plan or a carefully considered exemption from this requirement has been formulated.

Of the 294 vascular plant species classified as endangered in Pennsylvania, 112 (38%) are characteristic of GMS habitats (summarized in Tables 4 and 5, part C; identified in Appendix C). There are 86 species classified as threatened in the state, of which 35 (41%) live mainly in GMS habitats. Out of 110 vascular plant species that have been extirpated from Pennsylvania since European settlement, 38 (35%) are characteristic of grasslands, meadows, and savannas. These percentages are about double the 19.5% of the state's land currently estimated to be in grassland, meadow, and savanna 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 (R. E. Latham, unpublished data).

[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.

Table 4. Summary of native herbaceous vascular plants characteristic of grasslands, meadows, and savannas in Pennsylvania, categorized by wetland status, growth form, and rarity (includes all of the species summarized in Table 6). The species are listed in Appendices B and D.

A. Wetland status[1]	number of taxa
UPL	46
FACU–	38
FACU	92
FACU+	10
FAC–	15
FAC	80
FAC+	11
FACW–	9
FACW	84
FACW+	47
OBL	94
N	240
total	765

B. Growth form[2]	number of taxa
HA	142
HB	24
HP	594
VP	5
total	765

C. PNHP status[3]	number of taxa
PX	36
PE	102
PT	32
PR	18
TU	49
total	237

[1] Wetland status codes:

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
N	not rated

[2] Herbaceous plant growth-form codes:

HA	herbaceous annual
HB	herbaceous biennial
HP	herbaceous perennial
VP	herbaceous perennial vine

[3] State status codes:

PX	extirpated in the state
PE	endangered in the state
PT	threatened in the state
PR	rare in the state
TU	status tentatively undetermined and under study

Table 5. Summary of native woody plants characteristic of grasslands, meadows, and savannas in Pennsylvania, categorized by wetland status, growth form, and rarity. The species are listed in Appendices C and D.

A. Wetland status[1]	number of taxa
UPL	5
FACU–	7
FACU	16
FACU+	0
FAC–	4
FAC	11
FAC+	2
FACW–	3
FACW	5
FACW+	5
OBL	4
N	35
total	97

B. Growth form[2]	number of taxa
SD	62
SE	2
TD	18
TE	3
VW	12
total	97

C. PNHP status[3]	number of taxa
PX	2
PE	10
PT	3
PR	2
TU	5
total	22

[1] For wetland status codes, see footnote at Table 4, part A.

[2] Woody plant growth-form codes:

SD	deciduous shrub
SE	evergreen shrub
TD	deciduous tree
TE	evergreen tree
VW	woody vine

[3] For state status codes, see footnote at Table 4, part C.

Table 6. Summary of native herbaceous vascular plants wholly or mostly restricted in Pennsylvania to grasslands, meadows, and savannas, categorized by wetland status, growth form, and rarity (a subset of the species summarized in Table 4). The species are listed in Appendices B and D.

A. Wetland status[1]	number of taxa
UPL	26
FACU–	20
FACU	44
FACU+	5
FAC–	9
FAC	48
FAC+	4
FACW–	3
FACW	47
FACW+	38
OBL	76
N	108
total	428

B. Growth form[2]	number of taxa
HA	104
HB	15
HP	306
VP	3
total	428

C. PNHP status[3]	number of taxa
PX	26
PE	77
PT	22
PR	9
TU	31
total	165

Rare butterfly and moth species native to grasslands, meadows, and savannas in Pennsylvania

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 classified as endangered, threatened or rare in the state. Of these, 49 (74%) of the butterfly species and 45 (38%) of the moth species are known to depend in part or wholly on grasslands, meadows, and savannas because their larvae are specialist feeders on hosts that are native to these habitats (see Appendix E for a list of the species and known larval host plants). Even higher percentages of lepidopterans use GMS 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 barrens ecosystems and a subset of them is likely to depend on GMS habitats.

[1] For wetland status codes, see footnote at Table 4, part A.
[2] For herbaceous plant growth form codes, see footnote at Table 4, part B.
[3] For Pennsylvania Natural Heritage Program status codes, see footnote at Table 4, part C.

Discussion

Providing habitat for declining grassland-obligate birds

Pennsylvania's breeding bird fauna includes at least 15 species that are referred to as grassland-obligate or grassland-interior species (see Table 7), that is, in order to nest and successfully rear young they need access to large grasslands, meadows, or savannas, or to artificial habitats that supply at least some of the same nesting cues and resources. Such "imitation" GMS habitats include annual crop fields, hayfields, pastures, grassy reclaimed strip mines, and other areas that are mowed occasionally such as utility line rights-of-way and airport runway approaches.

"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). Conversion of some of the land in state parks and state game lands that is now in annual row crops, hay (non-native perennial cool-season grasses), or warm-season grass monocultures to diverse mixtures of native warm-season and cool-season grasses and forbs could greatly benefit these birds.

Grassland birds 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 8).

A large, contiguous habitat area is critical for all grassland species, and density, diversity and offspring survival increase with the size of a habitat "island." In Illinois, most grasshopper sparrows, savannah sparrows, bobolinks and Henslow's sparrows were absent from patches of less than 75 contiguous 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 150 acres (McWilliams and Brauning 2000). Furthermore, only a large contiguous area of grassland can be maintained as a habitat mosaic, large enough to accommodate patches of a variety of habitat types (Herkert 1994b). As a general rule of thumb in the Mid-Atlantic region, Peterjohn (2006) has suggested that GMS patches of 12 to 25 acres sometimes support a small "sink" population of a grassland-obligate bird species, 25 to 50-acre patches do so more consistently, and it takes a minimum of 100 to 250 acres of contiguous GMS to support multiple grassland-obligate bird species.

Table 7. Grassland-obligate bird species that nest in Pennsylvania and their conservation status in the state (McWilliams and Brauning 2000; Pennsylvania Natural Heritage Program 2007).

species	state status[1]
northern harrier (*Circus cyaneus*)	CA
northern bobwhite (*Colinus virginianus*)	
upland sandpiper (*Bartramia longicauda*)	PT
barn owl (*Tyto alba*)	CA
short-eared owl (*Asio flammeus*)	PE
loggerhead shrike (*Lanius ludovicianus*)	PE
horned lark (*Eremophila alpestris*)	
sedge wren (*Cistothorus platensis*)	PT
vesper sparrow (*Pooecetes gramineus*)	
savannah sparrow (*Passerculus sandwichensis*)	
grasshopper sparrow (*Ammodramus savannarum*)	
Henslow's sparrow (*Ammodramus henslowii*)	
dickcissel (*Spiza americana*)	PT
bobolink (*Dolichonyx oryzivorus*)	
eastern meadowlark (*Sturnella magna*)	

Henslow's sparrow

[1] State status codes:
- PE endangered in the state
- PT threatened in the state
- CA candidate at risk in the state

Table 8. Habitat preferences of grassland-obligate bird species that nest in Pennsylvania. Based on information in Peterjohn (2006) and McWilliams and Brauning (2000).

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	

In Appendix A, we list many specific locations where cutting fencerows and narrow strips of trees between fields is suggested to create much larger fields. Doing so, even when the resulting larger field is sinuous in shape, greatly enhances the attractiveness of GMS 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-obligate 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.

Some species require song perches within a particular height range, where males can advertise their territorial boundaries (Peterjohn 2006). Of the passerines, only 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 and stable enough to stay upright while bearing a bird's weight (see Table 8). No

grasses and few native forbs can serve the purpose (a non-native forb, common mullein, *Verbascum thapsus*, is regularly used). Randomly scattered shrubs, small trees, and dead snags are among the structural elements of native GMS that are critical to grassland-obligate birds.

When time, funds, and land are allocated to native GMS reclamation in the hopes of attracting nesting pairs of grassland-obligate 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-obligate birds and GMS 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, too, 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 GMS reclamation on state park and state game lands should be to provide source habitats for a variety of grassland-obligate bird species. A worthy secondary goal would be 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[1], 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 GMS reclamation project.

It should be noted that other bird species depend on native grasslands, meadows, and savannas in addition to the grassland-obligate nesters, and some of them are declining and considered to be species of conservation concern in the state. The long-eared owl (*Asio otus*), endangered in Pennsylvania, nests in conifers but forages in grasslands and marshes. The GMS users American

[1] 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).

woodcock (*Scolopax minor*), prairie warbler (*Dendroica discolor*), whip-poor-will (*Caprimulgus vociferus*), Wilson's snipe (*Gallinago delicata*), and yellow-breasted chat (*Icteria virens*) are listed as species of "maintenance concern" in the state wildlife action plan (Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2005).

The list of GMS wildlife species of conservation concern is not limited to birds. Other vertebrates depend on GMS habitats, including the least shrew (*Cryptotis parva*), eastern massasauga (*Sistrurus catenatus catenatus*), and Kirtland's snake (*Clonophis kirtlandii*), all endangered in Pennsylvania, and the shorthead garter snake (*Thamnophis brachystoma*), a Pennsylvania responsibility species[1] of maintenance concern. A host of insects and other arthropods utilize GMS habitats, including certain lepidopterans (see next section), 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 in the state 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 and their findings will doubtless inform GMS reclamation priorities and methods in the future.

Providing habitat for rare moths and butterflies of grasslands, meadows, and savannas

Hundreds of species of moths and butterflies utilize the native plants of the Commonwealth's grasslands, meadows, and savannas. Adults of a high proportion of these species feed on the nectar of GMS forbs. Most rare lepidopteran species in the state are narrowly specialized to feed as larvae on just one or two host plant species or genera, in many cases of plants that are characteristic of GMS habitats (see Results and Appendix E).

These animals have suffered declines just as grassland-obligate birds and GMS vascular plants have. One indication of the severity of the decline is how many species have already been extirpated from the state. At least seven GMS butterflies have been extirpated or are presumed extirpated from Pennsylvania, including the arogos skipper (*Atrytone arogos arogos*), pink-edged sulphur (*Colias interior*), mottled duskywing (*Erynnis martialis*), karner blue (*Lycaeides melissa samuelis*), tawny crescent (*Phyciodes batesii batesii*), green comma (*Polygonia faunus*), and checkered white (*Pontia protodice*). The corresponding number for moths is at least six species, including the barrens dagger moth (*Acronicta albarufa*), sweet underwing (*Catocala dulciola*), precious underwing (*Catocala pretiosa pretiosa*), marsh fern moth (*Fagitana littera*), slender clearwing (*Hemaris gracilis*), and Thaxter's pinion moth (*Lithophane thaxteri*).

Another indication of the magnitude of the risk to GMS lepidopterans is 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 eastern regal fritillary (*Speyeria idalia idalia*). At least twelve moths in the state that often utilize GMS habitats are globally rare: the barrens dagger moth (*Acronicta albarufa*), quiet underwing (*Catocala dulciola*), precious underwing moth (*Catocala pretiosa pretiosa*), bird dropping moth (*Cerma cora*), a hand-maid moth (*Datana ranaeceps*), slender clearwing (*Hemaris gracilis*), barrens itame (*Itame* sp. 1 nr. *inextricata*), Doll's merolonche (*Merolonche dolli*), flypoison borer moth (*Papaipema* sp. 1),

[1] Pennsylvania responsibility species are those for which the state plays an important regional, national, or global role in their conservation (Pennsylvania Game Commission and Pennsylvania Fish and Boat Commission 2005).

pink sallow (*Psectraglaea carnosa*), northeastern pine zale (*Zale curema*), and pine barrens zale (*Zale* sp. 1 nr. *lunifera*).

Key elements of GMS 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 feed for a longer period during the growing season than any one plant species is in flower. For instance, the eastern regal fritillary (*Speyeria idalia idalia*), a critically imperiled grassland butterfly whose sole remaining population lives in Pennsylvania, lives only where there is an abundance of violets (*Viola* spp.), its larval host plant; bunchgrasses (mainly little 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* and *C. pumilum*), which females rely on for nectar in late summer when laying eggs (Latham et al. 2007).

Promoting a high diversity of vascular plant species and habitat structure is a major key to benefiting moths and butterflies in GMS reclamation and management. The specific host plants of rare lepidopterans known to occur in the regions surrounding GMS reclamation projects should be special targets of the planting, monitoring, and management programs at all such sites on state parks and state game lands.

Increasing the diversity of native vascular plant species and management regimes used in grassland, meadow, and savanna reclamation

Native grassland, meadow, and savanna plant species that do not have official state status (endangered, threatened, rare, extirpated, or tentatively undetermined and under study) may be used in reclamation plantings without the need for a science-based recovery plan or a carefully considered exemption from this need. This palette of native plants (listed in Appendix A) consists of 60 grasses, 80 other graminoids (sedges and rushes), and 388 forbs. Of the grasses, 32 species have only the C_3 photosynthetic pathway (cool-season grasses) and 28 also have C_4 photosynthesis (warm-season grasses).

There are two ways of obtaining seeds of these species: purchase from a supplier and wild-collecting. At present relatively few of them are commercially available or in widespread use for GMS reclamation projects in Pennsylvania. Ernst Conservation Seeds, LLP, in Meadville, Pennsylvania is the largest supplier of GMS seeds of native Mid-Atlantic genotypes and has the widest selection of species. Its current inventory of regional genotypes includes 7 of the native cool-season grasses (6 of them from within Pennsylvania), 10 of the warm-season grasses (5 Pennsylvania), 14 of the other graminoids (13 Pennsylvania), and 65 of the forbs (58 Pennsylvania) listed in Appendix A. Although these are impressive numbers and growing year-by-year as more species' seeds are collected and propagated, they still represent only 18% of the native herbaceous species (but more than one-quarter of the grasses) most qualified for GMS reclamation planting (Appendix A). Reclamation practitioners who hope to attain levels of native plant species richness and wildlife habitat diversity comparable to historical and remnant native GMS stands have to include collection of native plant seeds from the wild as part of their reclamation protocols. Much care must be taken in choosing collection sites and in seed-collecting methods to avoid introducing seeds from non-native, invasive species in the mix and to avoid planted areas where non-native genotypes of native species have been introduced.

A few widespread misconceptions may need to be dispelled at the outset for some of those involved in the planning of GMS reclamation projects. For instance, not all native grasses are warm-season grasses and vice-versa; there are actually more species of *native* cool-season grasses than the number of commonly planted non-native grasses. Likewise, a monoculture — even a field of native warm-season grasses — in reality does *not* constitute good wildlife habitat (Norment et al. 1999; Peterjohn 2006). Patchy mixtures of cool-season grasses, warm-season grasses, forbs, and shrubs have been the norm in native grasslands, meadows, and savannas in the Mid-Atlantic region throughout the evolutionary history of wildlife species that depend on these habitats. Structural diversity also characterizes native GMS habitats; they were, and are, a mosaic of bare ground, sparse short vegetation, dense tall grasses and forbs, and scattered shrubs. Landscapes with a high diversity of native species, species functional groups, vegetation structure, and patchiness should be regarded as the desired outcome of reclamation projects (see Figure 5).

Diverse native GMS with a mix of native cool-season grasses, warm-season grasses, and forbs almost certainly support a higher biomass and diversity of wildlife than the mostly artificial environments that make up the majority of GMS or GMS-like habitats today, including annual crop fields, hayfields, pastures, old fields dominated by invasive non-native plants, reclaimed strip mines, and utility rights-of-way. Although few, if any, scientific studies have addressed the question directly, the basic ecological principles involved give weight to this hypothesis. Wildlife diversity and, in most cases, total biomass decrease toward the simpler or more homogeneous end of the spectrum of ecological communities, or as the proportion of plant cover in non-native species increases.

The food web is one of the most important factors contributing to this pattern. Insects are vital links in many of the food chains that make up the trophic web in terrestrial ecosystems. Many insects are specialist feeders to one degree or another, sometimes on a single plant species and often on a narrow range of plant species. A higher species richness of native plants entails a higher insect diversity and can support a higher insect biomass in a given area of land. Insects are the richest source of fats and protein for many small vertebrates, which are in turn food for many larger vertebrates. Higher plant species richness also means higher structural diversity of habitat for wildlife, which contributes to higher animal diversity and population numbers within a given area.

Non-native plants are eaten to a far lesser degree than native plants by insects and other herbivores. The relative lack of natural “enemies” (that is, consumers) is part of the reason why some non-native plant species are invasive. They have an unfair advantage over native plants, which have entire suites of co-evolved herbivores and parasites. With their lower average rates of herbivory, less of the biomass of non-native plants is converted into animal biomass. It is axiomatic that rich mixtures of native species, such as we see today mainly in the small, rare, historical GMS remnants, provided native wildlife species exactly what they needed for millions of years. After all, the native plants, the native vertebrates, and all of the native species in the food chains between them evolved together.

Converting those portions of state park lands and state game lands that are now devoted to annual crops, non-native cool-season hay species, or warm-season grass monocultures to species-rich, structurally diverse native GMS communities should be a high priority if high wildlife diversity as well as high game production is the goal. Annual crops in some cases foster high biomass and population numbers of one or a few game species, but the diversity of native wildlife they support is far lower than is supported by a diverse mixture of native plant species.

Figure 5. A (above). Part of a 175-acre meadow in Ricketts Glen State Park, Sullivan and Luzerne Counties. There is high diversity in native plant species and habitat structure, and the landscape is a patchy mosaic of areas with different soil moisture regimes, time since last disturbance, and type of disturbance. Such diversity at multiple scales enhances habitat quality for a wide variety of wildlife species. B (below). Switchgrass planting in Huntingdon County. High grass density, low species richness, low structural diversity, and lack of patchiness limits its value as habitat for wildlife.

Those rare remnants of historical GMS that are state-owned provide unique opportunities for the Department of Conservation and Natural Resources and the Game Commission to protect, restore and manage irreplaceable reference sites and rare, declining local genetic stock of many vascular plant species that are valuable for reclamation. Even the species found in these sites that are not listed as endangered or threatened in the state are imperiled in a sense, because the local genotypes are at risk of being swamped by inadvertent hybridization with planted stock of the same species, which until recently for many GMS plants have been predominantly from the Midwest and other sources outside the Mid-Atlantic region.

Undertaking grassland, meadow, and savanna reclamation or restoration

The initial approach to either reclamation or restoration of GMS involves site assessment. Sites should be classified broadly by soil/parent material type; cover types and their extent within the larger site; soil moisture; degree, pattern, and type of invasive cover; and an analysis of opportunities and constraints for restoration and reclamation. Sites can then be prioritized within a region or across the state to provide a mix of restoration and reclamation sites. Although restoration is perhaps more urgent from a conservation perspective, sites for restoration (those with existing native GMS remnants) are more limited. Such sites are often smaller, too, and one of the objectives of GMS restoration and reclamation is to create grasslands and meadows large enough to support grassland-interior birds — birds that require a minimum unfragmented area, often several hundred acres, in order to effectively reproduce. A regional or statewide GMS restoration/reclamation plan should take into account the need both for plant community restoration and for GMS reclamation and grassland-obligate bird recovery.

For reclamation sites, and in some cases even for restoration sites, it will be necessary to identify areas of heavy grass cover — cover heavy enough to exclude other species — and take steps to remedy this situation. For warm-season grasslands a late spring application of imazapic (Plateau®) with a three-week waiting period before trying to establish forbs is indicated. For cool-season grasses, an early season application of glyphosate (Roundup®) or similar material will suppress overly aggressive grass species. Again, it is necessary to wait three weeks before attempting plantings. In some specialized GMS, notably serpentine grassland/savanna that has been invaded by closed-canopy forest or woody vine cover, surface soil organic matter removal may be a necessary first step to restoring the grassland or savanna condition.

Plants for GMS reclamation or restoration are selected in a series of steps. First, there is a need to consult species lists compiled for this purpose or more comprehensive sources of information (for instance, Rhoads and Block 2007) that identify soil parent-material preferences of native plant species. The species lists then need to be filtered to yield those whose seeds are available from commercial suppliers or from sites available for wild-collecting, and further filtered to yield only those species that are appropriate for the local soil moisture regime. Nursery-raised plants can also be used if budget allows. For either seeds or plugs, it is important to make sure that the provenance of the plants is within or nearby Pennsylvania. Preferably, the seed or plant source should come from the same ecoregion as the site to be planted (see Appendix B for a local species availability listing; see www.nativeseednetwork.org for a map of Pennsylvania's ecoregions and the areas of the surrounding states into which they extend).

Planting a GMS can be challenging, because there is often a tendency for the planted native grass species to become over-dominant. This is particularly true of some of the warm-season grasses,

notably big bluestem, Indian grass, and switchgrass. It is best to mass forb plantings and separate them spatially from the grass plantings. This type of patchiness is common in nature and should be imitated to the extent possible in restoration and reclamation. In no cases should grasses be planted in rates exceeding 1 to 2 pounds per acre if the goal is to obtain high species diversity. For savanna systems, trees can be planted or released as volunteers. Sites may require post-planting maintenance to reduce grass cover. Prescribed burning and tillage have been used to reduce grass cover, as has selective herbiciding. Though still uncommon in the East as an ecosystem management tool, grazing at low density (less than 0.5 "animal units" — 1,000 pounds of grazer — per acre) should be considered as an alternative, especially in meadows. Grazing is widely used in Europe as a tool for the conservation management of native grasslands, meadows, savannas, and shrublands.

Failure of GMS plantings is not uncommon. In planning for restoration and reclamation, it should be very clear that failure is possible and beyond the control of even an excellent practitioner. Such temporary setbacks should be programmed into the operating plan for any grassland restoration/reclamation effort. The need for contingencies must be clear in the plan.

For many plants on the GMS species lists, seeds or planting stock may not be available commercially. In most restoration situations, commercially supplied seeds and planting stock are not appropriate in any case, because sustaining the site's unique set of genotypes, at least for the rarer species, is crucial to responsible stewardship of historical remnants and reference sites. In many cases, attaining levels of native plant species richness and wildlife habitat diversity comparable to historical and remnant native GMS stands would not be possible without collecting native plant seeds from the wild. Wild-collecting seed and raising seed stock in nursery beds in order to obtain seed (or plants) for planting should be planned for in any restoration/reclamation program. For rare species there are regulatory constraints on such activity, requiring state or federal agencies' approval of wild-collection and production of seed stock.

Once a grassland, meadow, or savanna is established, maintenance is required to keep the area from becoming shrubland or woodland, halt the spread of invasive, non-native species, maintain a mix of patches of different ages and species composition, and in some cases keep native grasses from crowding out other species. For grasslands and savannas with a strong warm-season grass component, prescribed burning in early to mid-spring may be the most effective way of suppressing non-native invaders and preventing succession to thicket or woods. Alternatively, unwanted woody or non-native plants may be spot-sprayed with triclopyr (Garlon IV®) or similar herbicide. For grasslands with a strong cool-season grass component, winter mowing can be used to suppress woody invasives. Fall or spring burning or spot-application of herbicide can also be used to discourage non-natives.

It is preferable to remove the cut material when mowing is used as a GMS management technique. Otherwise, thick litter builds up, which tends to speed the rate at which grasses competitively suppress other plants and advance toward monoculture (Bascompte and Rodríguez 2000). Mowing should be considered as a stopgap measure until a prescribed burning program can be put into place or restricted to special circumstances where burning is not practical. Mowing is not ecologically equivalent to burning or grazing, in part because it fails to create areas of bare soil, which are a requirement for some wildlife species and as sites for seed germination and colonization for less-competitive plant species. Patches of bare soil commonly develop in prescribed fire "hot spots" and in places where grazers uproot, trample, or wallow.

Prescribed burning should be rotated among patches in different years, with no more than one-fifth to one-third of a field or cluster of fields burned in any one year. This provides for quick recovery of local populations of wildlife that cannot escape the flames, including small mammals, reptiles, amphibians, insect larvae, eggs, and pupae, non-flying insects, spiders, and other non-flying and non-burrowing species. It also enhances habitat heterogeneity, providing for the needs of species with a wide range of habitat requirements.

With all of these recommendations in mind, it is important to note that a detailed, individual plan for each site should be drafted and vetted before proceeding with restoration or reclamation. It is recommended that a regional or statewide restoration/reclamation plan start with a few representative site types and that detailed plans, with contingencies, be written for each site.

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Appendix A. **Descriptions of potential native grassland/ meadow reclamation sites in state parks and state game lands in Pennsylvania**

Group 1. Fifteen counties south and east of Blue Mountain (Kittatinny Ridge)

State Game Lands 280, Berks County
Bedrock: phyllitic (slaty) shale; small areas of limestone
Description: Large and small clusters of cultivated fields separated by fencerows, partly surrounded by woods and partly by adjoining neighboring landowners' cultivated fields, with a small amount of road frontage. Game land tracts are separated by Blue Marsh Lake and surrounding federal lands managed by the U.S. Army Corps of Engineers, much of which is also in highly fragmented cultivated fields. Cutting fencerows and clearing some brushy old fields could create as few as seven fields: three north of the upper end of the reservoir of about 625, 400 and 160 acres; two north of the main part of the reservoir of approximately 330 and 30 acres, and two west of the reservoir of about 130 and 110 acres.

State Game Lands 182, Berks County
Bedrock: shale, greywacke (clayey sandstone), phyllitic (slaty) shale
Description: Three isolated, small clusters of cultivated fields separated by fencerows, mostly surrounded by woods (35, 19, 14 acres).

Middle Creek Wildlife Management Area (State Game Lands 46), Lancaster and Lebanon Counties
Bedrock: sandstone, quartz-pebble conglomerate; may be some shale
Description: Large clusters of fields with only a few fencerows, mostly surrounded by woods and the shore of Middle Creek Lake, with some road frontage. With minor brush cutting, they could become as few as three large and two small fields: on the northeastern side of the reservoir, 920, 180 and 28 acres; on the northwestern side of the reservoir, 430 and 25 acres.

State Game Lands 145, Lebanon County
Bedrock: shale, sandstone, quartz conglomerate; may be some argillite
Description: A single cluster of fields separated by fencerows in the northwestern corner. Could be joined by cutting fencerows into a single field of about 145 acres.

State Game Lands 220, Lancaster County
Bedrock: quartzose sandstone, quartz conglomerate
Description: A single cultivated field of nearly 70 acres adjoining neighboring landowners' cultivated fields on three sides and the wooded part of the gameland on the other side.

State Game Lands 80, Lebanon County
Bedrock: sandstone, siltstone, shale, small area of limestone, calcareous shale, dolomite
Description: One field between I-81 and the Appalachian Trail of nearly 60 acres.

Evansburg State Park, Montgomery County
Bedrock: shale, mudstone, siltstone, argillite; may be some calcareous shale
Description: Widely scattered clusters of cultivated fields separated by fencerows and mowed turf areas (including a golf course), mostly surrounded by brushy old fields and woods with

minor frontage on neighboring landowners' cultivated fields and suburban residential areas. Site is bisected by the wooded riparian corridor of Skippack Creek. Clusters could be joined by cutting fencerows and clearing a few small brushy areas into as few as 10 fields: near the northeastern end, three fields of about 300, 70 and 30 acres; near the center, three fields of about 125, 25 and 20 acres; near the southwestern end, four fields of about 75, 55, 35 and 18 acres. Even larger fields could be created with more extensive clearing of brushy old fields.

Norristown Farm Park, Montgomery County (state park managed by Montgomery County Department of Parks and Heritage Services)
Bedrock: arkosic (feldspar-rich) sandstone; may be some shale, siltstone
Description: Three field complexes separated by a Y-shaped wooded riparian corridor along Stony Creek and one of its tributaries, Five Mile Run, surrounded by woods, suburban residential and institutional development, and roads. Minimal fencerow cutting could create three large fields of approximately 230, 220 and 120 acres.

State Game Lands 234, Montgomery County (tract near Schwenksville)
Bedrock: shale, mudstone, siltstone, argillite
Description: Cultivated fields, some separated by fencerows, mostly surrounded by woods and with some frontage on a few neighboring landowners' cultivated fields, residential lots, roads, a railroad, and an industrial area. Fencerow cutting in the southwestern tract could create a single field of about 140 acres. Four fields in the northeastern tract (formerly the Fisher State Game Farm or Eastern Game Farm) range in size from 16 to 75 acres and total 135 acres.

Tyler State Park, Bucks County
Bedrock: arkosic (feldspar-rich) sandstone, argillite; may be some shale, siltstone
Description: Large and small clusters of cultivated fields separated by fencerows, mostly surrounded by woods and with minor frontage on a few neighboring landowners' cultivated fields. Could be joined by cutting fencerows and clearing some adjoining brushy old fields to create as few as four large fields: at the eastern end, about 200 acres; southwestern corner, at least 250 acres; northwestern side, at least 325 acres; northern end, about 75 acres.

Nockamixon State Park, Bucks County
Bedrock: shale, mudstone, siltstone
Description: Two clusters of old fields recently planted in warm-season grasses, surrounded by woods: one north of Lake Nockamixon of 35 acres and one south of the reservoir and west of the dam of 55 acres. Brushy old fields are extensive along a 5-mile long, 2,000 to 3,000-foot wide strip of the park between Pa. 563 and the shore of the reservoir, dominated by invasive shrubs and small trees such as common buckthorn (*Rhamnus cathartica*), autumn-olive (*Elaeagnus umbellata*), and multiflora rose (*Rosa multiflora*). Clearing and planting could create one or more fields of up to perhaps 500 acres.

Neshaminy State Park, Bucks County
Bedrock: gravelly sand; may be some sand and clay-silt
Description: Three brushy old fields underlain in part by river-bottom dredging spoil and surrounded by woods, urban development, and stream frontage on the Delaware River and Neshaminy Creek, totaling 65 acres. The site provides a special opportunity to restore coastal plain grassland type; many of the species native to this type are still growing and reproducing on the site. Control of invasives, including black locust (*Robinia pseudoacacia*) and mile-a-minute weed (*Persicaria perfoliata*), is essential.

Tyler State Park, Bucks County
Bedrock: arkosic (feldspar-rich) sandstone, argillite; may be some shale, siltstone
Description: Large and small clusters of cultivated fields separated by fencerows, mostly surrounded by woods and with minor frontage on a few neighboring landowners' cultivated fields. Could be joined by cutting fencerows and clearing some adjoining brushy old fields to create as few as four large fields: at the eastern end, about 200 acres; southwestern corner, at least 250 acres; northwestern side, at least 325 acres; northern end, about 75 acres.

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State Game Lands 249, Adams County
Bedrock: shale, sandstone; may be some quartzite, argillite
Description: Scattered clusters of cultivated fields mostly adjoining neighboring landowners' cultivated fields and partly surrounded by woods. The larger clusters could be joined by cutting fencerows and clearing some adjoining brushy old fields to create as few as ten fields: two in the western tract, at least 475 acres and 45 acres; three in the two middle tracts, about 140, 90 and 15 acres; and five in the eastern tract, approximately 150, 100, 100, 80 and 20 acres.

State Game Lands 235, Franklin County
Bedrock: magnesium limestone; may be some shale
Description: Two small clusters of cultivated fields separated by fencerows, mostly surrounded by woods. Cutting fencerows could create fields of about 50 and 30 acres.

Caledonia State Park, Franklin and Adams Counties
Bedrock: metarhyolite (metamorphosed silica-rich volcanic rock)
Description: Golf course of about 70 acres, surrounded by woods.

State Game Lands 169, Cumberland County
Bedrock: shale, sandstone, greywacke (clayey sandstone)
Description: Large and small clusters of cultivated fields separated by fencerows, partly surrounded by woods and partly by adjoining neighboring landowners' cultivated fields. Site is bisected by the mostly wooded riparian corridor of Conodoguinet Creek. The larger clusters could be joined by cutting fencerows and clearing some adjoining brushy old fields to create as

few as six large fields: on the northwestern side, about 260 acres; from the western end through the center, at least 575 acres; northern end, about 40 acres; south of Conodoguinet Creek, three fields of 125, 65 and 65 acres. Two other fields of about 18 acres each also lie south of the creek.

White Clay Creek State Park, Chester County
Bedrock: schist, marble, pegmatite, hornblende-bearing mafic gneiss
Description: Fragmented cultivated fields separated by fencerows, mostly surrounded by woods and with minor frontage on a few neighboring landowners' cultivated fields and residential lots. Site is bisected by the mostly wooded riparian corridor of White Clay Creek. Clusters could be joined by cutting fencerows to create eight larger fields: one on the north-central side of about 125 acres and seven others scattered around the park, ranging in size from 12 to 85 acres and totaling about 340 acres.

Marsh Creek State Park, Chester County
Bedrock: graphitic gneiss, gabbroic gneiss, gabbro, metadiabase dikes
Description: Clusters of cultivated fields separated by fencerows, surrounded by woods, the shore of Marsh Creek Lake, neighboring landowners' cultivated fields, and suburban residential areas. Could be joined by cutting fencerows to create as few as four fields: southwest of the reservoir, about 145 acres; northwest, about 150 acres; and northeast, two fields of about 80 and 40 acres.

State Game Lands 43, Chester County
Bedrock: gabbroic gneiss, gabbro, quartz monzonite, quartz monzonite gneiss; small areas of arkosic sandstone, siltstone, shale, sheet diabase, graphitic gneiss
Description: Clusters of cultivated fields separated by fencerows, partly surrounded by woods and partly by adjoining neighboring landowners' cultivated fields. Could be joined by cutting fencerows to create as few as five fields: in the middle tract, 160, 45, 40 and 25 acres; in the eastern tract, 50 acres.

State Game Lands 243, York County
Bedrock: sheet diabase, shale, sandstone, argillite
Description: Widely scattered cultivated fields, mostly surrounded by woods. The central cluster could be joined by cutting fencerows and expanded by clearing some adjoining brushy old fields to create a single field of at least 200 acres. Three other fields (60, 60 and 30 acres) adjoin both woods and neighboring landowners' cultivated fields.

State Game Lands 242, York County
Bedrock: sheet diabase
Description: Fragmented cultivated fields, mostly surrounded by woods. A cluster on the eastern side could be joined by cutting fencerows and expanded by clearing some adjoining brushy old fields to create a single field of at least 160 acres. A cluster on the western side adjoining a neighboring landowner's cultivated field could be joined by cutting fencerows and expanded by clearing some adjoining brushy old fields to create a field of at least 60 acres. Three other fields (30, 25 and 13 acres) are surrounded by woods.

Codorus State Park, York County
Bedrock: quartzite, quartz schist, mica-chlorite-quartzite schist
Description: Widely scattered, small cultivated fields or turf areas, mostly surrounded by woods, roads, and shore of Lake Marburg and with minor frontage on a few neighboring landowners' cultivated fields and residential lots and recreation areas within the park. There may be as many

as six potential grassland reclamation areas, ranging in size from 12 to 50 acres and totaling about 165 acres.

State Game Lands 83, York County
Bedrock: albite-chlorite schist
Description: A single cluster of fields mostly surrounded by woods. Could be joined by cutting fencerows to create a single field of about 70 acres.

State Game Lands 181, York County
Bedrock: albite-chlorite schist
Description: Fragmented cultivated fields, mostly surrounded by woods. A cluster on the western side could be joined by cutting fencerows and expanded by clearing some adjoining brushy old fields to create a single field of at least 45 acres. One other field of 18 acres adjoins a neighboring landowner's cultivated field on one side.

State Game Lands 205, Lehigh County
Bedrock: shale, greywacke (clayey sandstone)
Description: Highly fragmented cultivated fields separated by fencerows, mostly surrounded by woods and with minor frontage on a few neighboring landowners' cultivated fields. Located just west of the Trexler Game Preserve. Cutting fencerows and clearing some small brushy areas could create nine larger fields, ranging in size from 25 to 100 acres and totaling about 425 acres.

Ridley Creek State Park, Delaware County
Bedrock: hornblende-bearing and pyroxene-bearing felsic gneiss
Description: Scattered old fields, horse pastures, and cultivated fields, some with fencerows, mostly surrounded by woods. Cutting fencerows and clearing brushy old fields could create up to six fields, ranging in size from 18 to 65 acres and totaling about 200 acres.

Jacobsburg State Park, Northampton County
Bedrock: shale; may be some siltstone, metabentonite (claystone metamorphosed from volcanic ash), sandstone
Description: A single cluster of brushy old fields south of Bushkill Creek in various stages of succession, separated by old fencerows and surrounded by woods, a neighboring landowner's cultivated field, and suburban residences. Could be joined by clearing brush and cutting fencerows to create a single field of about 190 acres.

Benjamin Rush State Park, Philadelphia County
Bedrock: schist, sand and gravel (mostly of quartz, quartzite, and chert)
Description: Three adjoining fields separated by narrow fencerows, surrounded by woods and urban development. Part of the site is used for community gardens. The remainder could be joined by cutting fencerows to create a field as large as 125 acres.

Group 2. Scattered locations north and west of Blue Mountain (Kittatinny Ridge)

Moraine State Park, Butler County
Bedrock: sandstone, shale, limestone, clay, coal; bedrock in small part in northwestern corner may be overlain by glacial drift
Description: Cultivated fields or recently abandoned old fields at the eastern end around the upper reaches of the Swamp Run arm of Lake Arthur and in the northwestern corner. They are partly surrounded by woods and partly by either adjoining landowners' cultivated fields or the shore of the reservoir. Some brush-cutting could create six fields: three at the eastern end of about 140, 100 and 70 acres and three in the northwestern corner of 45, 30 and 25 acres. In addition, there is a network of old fields or reclaimed strip mines on both sides of Pa. 528 north of the upper reaches of reservoir arm where Muddy Creek flows in, mostly surrounded by woods. The more open portion totals about 650 contiguous acres in a sinuous shape nearly surrounding a central wooded area. Extensive brush-cutting could create a single field of this size or a series of smaller fields.

Ricketts Glen State Park, Sullivan & Luzerne Counties
Bedrock: sandstone; may be some shale, siltstone
Description: An old field north of Lake Jean and south of the U.S. Air Force installation of about 175 acres. It is already a diverse mosaic of mostly native grasslands, meadows, and shrublands, lacking only newly disturbed (burned or scraped) areas to have a complete array of the grassland and meadow habitats typical of this region of the state. There is also an extensive area of hay-scented fern savanna on Red Rock Mountain in the western part of the park totaling over 200 acres. This community is a result of prolonged, extreme white-tailed deer density and is low in diversity and value as wildlife habitat. Herbiciding the ferns and planting native grassland and meadow species could greatly increase its value.

Bald Eagle State Park, Centre County
Bedrock: siltstone, shale, sandstone
Description: Brushy old fields along 2¼ miles of Pa. 150 southwest of Schencks Cemetery, with woods along the side away from the road and toward the shore of Foster Joseph Sayers Reservoir. Clearing could create a single field of about 290 acres.

Shawnee State Park, Bedford County
Bedrock: siltstone, shale, sandstone; may be some calcareous shale, argillaceous limestone, chert
Description: Three areas of relatively open old fields west of Shawnee Lake, mostly surrounded by woods, roads, and the reservoir and with minor frontage on a few neighboring landowners' cultivated fields and residential lots. Brush clearing could create fields of at least 80, 75 and 40 acres.

Tuscarora State Park, Schuylkill County
Bedrock: shale, claystone, sandstone, siltstone
Description: Two cultivated fields or turf areas north and northwest of Tuscarora Lake, 40 and 35 acres. Several brushy old fields and cultivated fields south and southwest of the reservoir, including three in the range of 18 to 20 acres.

M. K. Goddard State Park, Mercer County
Bedrock: sandstone, siltstone, shale; may be overlain in part by glacial drift
Description: Old fields at and east of the northern end of Lake Wilhelm Road bridge, surrounded

by woods, Georgetown Road, and the shore of Lake Wilhelm. Brush clearing could create two fields of 50 and 30 acres. A cluster of cultivated fields separated by fencerows south of the intersection of Georgetown and Deer Creek Roads, surrounded by woods, Georgetown Road, and the shore of Lake Wilhelm. Cutting fencerows could create a field of about 100 acres.

Nescopeck State Park, Luzerne County
Bedrock: calcareous sandstone; bedrock may be overlain in part by glacial drift
Description: Old fields near the southwestern end, between Nescopeck Creek and the park access road, surrounded by woods. Extensively invaded by non-native species such as autumn-olive (*Elaeagnus umbellata*). Brush clearing could create fields of 65 and 16 acres. Similar but smaller brushy old fields lie along the foot of Mt. Yeager farther eastward.

Appendix B. **Herbaceous vascular plant species commonly inhabiting long-lived grasslands, meadows, and savannas in Pennsylvania**

(*N* = 528). Endangered, threatened, and rare species of special concern in Pennsylvania are not listed here; see Appendix D. Taxonomy, wetland status[1], and growth form[2] are from Rhoads and Block (2007). Entries under Ernst Seeds are state abbreviations for the locations of wild-collected seeds of native genotypes sold in 2007-2008 by Ernst Conservation Seeds, L.L.P., the largest supplier of such seeds in the region (www.ernstseed.com, 9006 Mercer Pike, Meadville, PA 16335, 800-873-3321).

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
SPIKEMOSSES AND CLUBMOSSES					
Lycopodiaceae					
Diphasiastrum tristachyum [= *Lycopodium tristachyum*]	deep-rooted running-pine	N	HP		
Lycopodium clavatum [= *L. lagopus*]	one-cone clubmoss	FAC	HP		
Lycopodium dendroideum	tree ground-pine, northern tree clubmoss, prickly tree clubmoss	FACU	HP		
Selaginellaceae					
Selaginella apoda	meadow spikemoss	FACW	HP		
FERNS AND HORSETAILS					
Ophioglossaceae					
Botrychium dissectum [= *B. obliquum*]	cut-leaved grape-fern	FAC	HP		

[1] Wetland status codes:

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
N	not rated

[2] Growth-form codes:

HA	herbaceous annual
HB	herbaceous biennial
HP	herbaceous perennial
VP	herbaceous perennial vine

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Botrychium multifidum	leathery grape fern, northern grape fern	FACU	HP		
Botrychium simplex	least moonwort, least grape-fern	FACU	HP		
Equisetaceae					
Equisetum arvense	field horsetail, devil's-guts	FAC	HP		
Equisetum hyemale	scouring-rush	FACW	HP		
Equisetum sylvaticum	woodland horsetail	FACW	HP		
Ophioglossaceae					
Ophioglossum pusillum [= *O. vulgatum* var. *pseudopodum*]	northern adder's-tongue	N	HP		
Polypodiaceae					
Dennstaedtia punctilobula	hay-scented fern	N	HP		
Onoclea sensibilis	sensitive fern	FACW	HP		PA
Pteridium aquilinum	northern bracken fern	FACU	HP		
Thelypteris palustris	marsh fern	FACW+	HP		
FLOWERING PLANTS					
Melanthiaceae					
Amianthium muscaetoxicum	fly-poison	FAC	HP		
Chamaelirium luteum	devil's-bit, fairy-wand	FAC	HP		
Liliaceae					
Erythronium americanum	yellow trout-lily	N	HP		
Lilium canadense ssp. *canadense*	Canada lily	FAC+	HP		
Lilium philadelphicum	wood lily	FACU+	HP		
Lilium superbum	Turk's-cap lily	FACW+	HP		PA
Orchidaceae					
Calopogon tuberosus	grass-pink	FACW+	HP		

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Liparis loeselii	yellow twayblade	FACW	HP		
Platanthera grandiflora	large purple fringed-orchid	FACW	HP		
Platanthera lacera	ragged fringed-orchid	FACW	HP		
Pogonia ophioglossoides	rose pogonia	OBL	HP		
Spiranthes cernua	nodding ladies'-tresses	FACW	HP		
Spiranthes lacera var. *gracilis*	southern slender ladies'-tresses	FACU–	HP		
Spiranthes lacera var. *lacera*	northern slender ladies'-tresses	FACU–	HP		
Spiranthes ochroleuca	yellow nodding ladies'-tresses	FACW	HP		
Hypoxidaceae					
Hypoxis hirsuta	yellow star-grass	FAC	HP		
Iridaceae					
Sisyrinchium angustifolium	narrow-leaved blue-eyed-grass	FACW–	HP		PA
Sisyrinchium montanum var. *crebrum*	mountain blue-eyed-grass	FAC	HP		
Sisyrinchium mucronatum	needletip blue-eyed-grass	FAC+	HP		
Alliaceae					
Allium cernuum	nodding onion	N	HP		OH
Ruscaceae					
Maianthemum stellatum [= *Smilacina stellata*]	starflower	N	HP		
Polygonatum biflorum var. *biflorum*	smooth Solomon's-seal	FACU	HP		
Polygonatum biflorum var. *commutatum*	smooth Solomon's-seal	FACU	HP		
Polygonatum pubescens	hairy Solomon's-seal	N	HP		
Juncaceae					
Juncus acuminatus	sharp-fruited rush	OBL	HP		
Juncus secundus	lopsided rush	FACU	HP		
Juncus tenuis var. *tenuis*	path rush	FAC–	HP		PA

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Luzula echinata [= *L. campestris* var. *echinata*]	common woodrush	FACU	HP		
Cyperaceae					
Bulbostylis capillaris	sandrush	FACU	HA		
Carex aggregata [= *C. sparganioides* var. *aggregata*]	glomerate sedge	FACU	HP		
Carex albolutescens	green-white sedge, pale straw sedge	FACW	HP		NC
Carex amphibola	eastern narrow-leaved sedge	FAC	HP		
Carex annectens [= *C. vulpinoidea* var. *ambigua, C. xanthocarpa*]	yellow-fruited sedge	FACW	HP		
Carex arctata	drooping woodland sedge	OBL	HP		
Carex argyrantha	hay sedge, silvery sedge	N	HP		
Carex baileyi	Bailey's sedge	OBL	HP		PA
Carex blanda [= *C. laxiflora* var. *blanda*]	eastern woodland sedge	FAC	HP		
Carex bromoides	brome-like sedge	FACW	HP		
Carex brunnescens	brownish sedge	FACW	HP		
Carex bushii	Bush's sedge	FACW	HP		
Carex canescens var. *canescens*	silvery sedge	OBL	HP		
Carex canescens var. *disjuncta*	silvery sedge	OBL	HP		
Carex caroliniana	Carolina sedge	FACU	HP		
Carex cephaloidea [= *C. sparganioides* var. *cephaloidea*]	thin-leaved sedge	FAC+	HP		
Carex cephalophora	oval-headed sedge	FACU	HP		
Carex communis	fibrous-root sedge, colonial oak sedge	N	HP		
Carex conjuncta	soft fox sedge	FACW	HP		
Carex conoidea	open-field sedge	FACU	HP		

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Carex cristatella	crested sedge	FACW	HP		
Carex cumulata	clustered sedge	FACU	HP		
Carex glaucodea [= *C. flaccosperma* var. *glaucodea*]	blue sedge	N	HP		
Carex gracilescens	slender loose-flower sedge	N	HP		
Carex granularis var. *granularis*	limestone meadow sedge	FACW+	HP		
Carex granularis var. *haleana*	limestone meadow sedge	FACW+	HP		PA
Carex grisea [= *C. amphibola* var. *turgida*]	eastern narrow-leaved sedge, gray sedge	FAC	HP		
Carex hirsutella [= *C. complanata* var. *hirsuta*]	fuzzy wuzzy sedge	N	HP		
Carex interior	inland sedge	OBL	HP		
Carex intumescens	greater bladder sedge	FACW+	HP		PA
Carex leavenworthii	Leavenworth's sedge	N	HP		
Carex lucorum	Blue Ridge sedge	N	HP		
Carex lurida	lurid sedge, shallow sedge	OBL	HP		PA
Carex mesochorea [= *C. cephalophora* var. *mesochorea*]	midland sedge	FACU	HP		
Carex molesta [= *C. brevior*]	field oval sedge, troublesome sedge	N	HP		
Carex muhlenbergii	Mühlenberg's sedge	N	HP		
Carex nigromarginata	black edge sedge	UPL	HP		
Carex normalis	greater straw sedge	FACU	HP		PA
Carex pallescens	pale sedge	N	HP		
Carex pellita	woolly sedge	OBL	HP		
Carex scoparia	broom sedge	FACW	HP		PA
Carex sparganioides	bur-reed sedge	FACU	HP		
Carex stipata var. *stipata*	stalk-grain sedge, owlfruit sedge	N	HP		PA

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Carex swanii	downy green sedge, Swan's sedge	FACU	HP		PA
Carex tenera var. *tenera*	marsh straw sedge, quill sedge	FAC	HP		
Carex tonsa var. *rugosperma*	parachute sedge	N	HP		
Carex tonsa var. *tonsa*	shaved sedge	N	HP		
Carex tribuloides var. *tribuloides*	blunt broom sedge, bristlebract sedge	FACW+	HP		PA
Carex trichocarpa	hairy-fruited sedge	OBL	HP		
Carex umbellata	parasol sedge	N	HP		
Carex vestita	velvet sedge	N	HP		
Carex vulpinoidea	fox sedge, brown fox sedge	OBL	HP		PA
Cyperus acuminatus	short-pointed flatsedge	OBL	HA		
Cyperus bipartitus	slender flatsedge, umbrella sedge	FACW+	HA		
Cyperus echinatus [= *C. ovularis*]	globe flatsedge, umbrella sedge	FACU	HP		
Cyperus esculentus	yellow nutsedge	FACW	HP		
Cyperus flavescens	yellow flatsedge, umbrella sedge	OBL	HA		
Cyperus lupulinus [= *C. filiculmis*]	Great Plains flatsedge, sand sedge	UPL	HP		
Cyperus odoratus	rusty flatsedge, umbrella sedge	FACW	HA		
Cyperus plukenetii [= *C. retrofractus* var. *retrofractus*]	Plukenet's flatsedge	N	HP		
Cyperus retrofractus	rough flatsedge	N	HP		
Cyperus strigosus	false nutsedge	FACW	HP		
Cyperus tenuifolius [= *Kyllinga pumila*]	thin-leaved flatsedge	FACW	HA		
Eleocharis engelmannii	Engelmann's spike-rush	FACW+	HA		
Eleocharis erythropoda	bald spike-rush	OBL	HP		
Eleocharis tenuis var. *pseudoptera*	slender spike-rush	FACW+	HP		
Eleocharis tenuis var. *tenuis*	slender spike-rush	FACW+	HP		

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Fimbristylis autumnalis	slender fimbry	FACW+	HA		
Rhynchospora capitellata	brownish beaksedge	OBL	HP		
Scirpus atrovirens	black bulrush	OBL	HP		PA
Scirpus cyperinus	wool-grass	FACW+	HP		PA
Scirpus expansus	wood bulrush	OBL	HP		PA
Scirpus georgianus	Georgia bulrush	OBL	HP		
Scirpus hattorianus	mosquito bulrush	OBL	HP		
Scirpus microcarpus	panicled bulrush	OBL	HP		
Scirpus pendulus	rufous bulrush	OBL	HP		
Poaceae					
Agrostis hyemalis	ticklegrass, spring bentgrass	FAC	HP	C_3	NC
Agrostis perennans	autumn bentgrass, upland bentgrass	FACU	HP	C_3	PA
Agrostis scabra [= *A. hyemalis* var. *scabra*]	fly-away grass, ticklegrass, rough bentgrass	FAC	HP	C_3	PA
Alopecurus carolinianus	Carolina foxtail, tufted foxtail	FACW	HA	C_3	
Andropogon gerardii [= *A. furcatus*]	big bluestem, turkeyfoot	FAC–	HP	C_4	NY
Andropogon virginicus	broom-sedge	FACU	HP	C_4	
Aristida longespica var. *longespica*	slender threeawn	UPL	HA	C_4	
Aristida oligantha	prairie threeawn	N	HA	C_4	
Bromus ciliatus	fringed brome	FACW	HP	C_3	
Calamagrostis canadensis var. *canadensis*	Canada bluejoint	FACW+	HP	C_3	
Calamagrostis canadensis var. *macouniana*	Canada bluejoint	FACW+	HP	C_3	
Danthonia compressa	northern oatgrass	FACU–	HP	C_3	
Danthonia spicata	poverty grass, poverty oatgrass	N	HP	C_3	
Deschampsia flexuosa	wavy hairgrass, common hairgrass	N	HP	C_3	

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Dichanthelium acuminatum [= *Panicum acuminatum*]	tapered rosette grass	FAC	HP	C_3	
Dichanthelium boscii [= *Panicum boscii*]	Bosc's panic grass	N	HP	C_3	
Dichanthelium clandestinum [= *Panicum clandestinum*]	deer-tongue, deer-tongue grass	FAC+	HP	C_3	PA
Dichanthelium columbianum [= *D. sabulorum* var. *thinium, Panicum columbianum*]	hemlock rosette grass	N	HP	C_3	
Dichanthelium commutatum ssp. *ashei* [= *Panicum ashei, P. boscii* x *commutatum*]	variable panic grass	N	HP	C_3	
Dichanthelium commutatum ssp. *commutatum* [= *Panicum commutatum*]	oval-leaved panic grass	FACU+	HP	C_3	
Dichanthelium depauperatum [= *Panicum depauperatum*]	poverty panic grass	N	HP	C_3	
Dichanthelium latifolium [= *Panicum latifolium*]	broadleaf rosette grass	FACU–	HP	C_3	
Dichanthelium linearifolium [= *Panicum linearifolium*]	slim-leaved witch grass	N	HP	C_3	
Dichanthelium sphaerocarpon [= *Panicum sphaerocarpon*]	round-fruited panic grass, round-seeded panic grass	FACU	HP	C_3	
Digitaria cognata [= *D. cognatum, Leptoloma cognatum*]	fall witchgrass	N	HP	C_4	
Digitaria filiformis	slender crabgrass	N	HA	C_4	
Echinochloa muricata	rough barnyard-grass, cockspur	FACW+	HA	C_4	
Elymus canadensis var. *canadensis*	Canada wild-rye	FACU+	HP	C_3	
Elymus riparius	riverbank wild-rye	FACW	HP	C_3	PA
Elymus virginicus	Virginia wild-rye	FACW–	HP	C_3	PA
Eragrostis capillaris	lacegrass	N	HA	C_4	

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Eragrostis spectabilis	purple lovegrass, tumblegrass	UPL	HP	C_4	VA
Festuca obtusa [= *F. subverticillata*]	nodding fescue	FACU	HP	C_3	
Hordeum jubatum	foxtail-barley	FAC	HP	C_3	
Leersia oryzoides	rice cutgrass	OBL	HP	C_3	PA
Leptochloa fascicularis [= *L. fusca* ssp. *fascicularis*]	sprangletop	FACW	HA	C_4	
Muhlenbergia frondosa	wirestem muhly	FAC	HP	C_4	
Muhlenbergia mexicana	Mexican muhly satingrass	FACW	HP	C_4	
Panicum anceps	beaked panic grass	FAC	HP	C_4	MD
Panicum capillare	witchgrass	FAC–	HA	C_4	
Panicum dichotomiflorum [= *P. proliferum*]	smooth panic grass	FACW–	HA	C_4	PA
Panicum gattingeri [= *P. capillare* (in part)]	Gattinger's panic grass	FAC	HA	C_4	
Panicum philadelphicum [= *P. capillare* (in part)]	Philadelphia panic grass	FAC–	HA	C_4	
Panicum rigidulum [= *P. agrostoides, P. condensum*]	red-top panic grass	FACW+	HP	C_4	PA
Panicum stipitatum [= *P. rigidulum* var. *elongatum*]	tall flat panic grass	FACW+	HP	C_4	
Panicum virgatum	switchgrass	FAC	HP	C_4	WV
Paspalum laeve	field beadgrass	FAC+	HP	C_4	
Phalaris arundinacea	reed canary-grass	FACW	HP	C_3	
Poa palustris	fowl bluegrass	FACW	HP	C_3	
Schizachyrium scoparium var. *scoparium*	little bluestem	FACU	HP	C_4	PA
Setaria parviflora	perennial foxtail	FAC	HP	C_4	
Sorghastrum nutans	Indian-grass	UPL	HP	C_4	PA, VA
Spartina pectinata	prairie cordgrass, freshwater cordgrass	OBL	HP	C_4	PA

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Sphenopholis nitida	wedgegrass, shiny wedgescale	N	HP	C_3	
Sphenopholis obtusata var. *major*	slender wedgegrass	FAC–	HP	C_3	
Sphenopholis obtusata var. *obtusata*	prairie wedgegrass	FAC–	HP	C_3	
Sphenopholis pensylvanica	swamp-oats	OBL	HP	C_3	
Sporobolus cryptandrus	sand dropseed	UPL	HP	C_4	
Sporobolus vaginiflorus	poverty grass, poverty dropseed	UPL	HA	C_4	
Tridens flavus	purpletop	FACU	HP	C_4	VA
Commelinaceae					
Tradescantia ohiensis	Ohio spiderwort, blue-jacket	FAC	HP		PA
Tradescantia virginiana	spiderwort, widow's-tears, Virginia spiderwort	FACU	HP		PA, VA
Ranunculaceae					
Anemone canadensis	Canada anemone	FACW	HP		PA
Caltha palustris	marsh-marigold	OBL	HP		
Ranunculus abortivus	small-flowered crowfoot	FACW–	HA		
Ranunculus hispidus var. *caricetorum*	marsh buttercup, northern swamp buttercup	FAC	HP		
Ranunculus pensylvanicus	bristly crowfoot	OBL	HA / HP		
Thalictrum pubescens	tall meadow-rue	FACW+	HP		PA
Thalictrum revolutum	purple meadow-rue, skunk meadow-rue	UPL	HP		
Papaveraceae					
Sanguinaria canadensis	bloodroot, red puccoon	UPL	HP		
Polygonaceae					
Persicaria arifolia [= *Polygonum arifolium*]	halberd-leaf tearthumb	OBL	HA		PA
Persicaria hydropiperoides [= *Polygonum hydropiperoides*]	mild water-pepper, water-smartweed	OBL	HP		

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Persicaria pensylvanica [= *Polygonum pensylvanicum*]	Pennsylvania smartweed, pinkweed	FACW	HA		
Persicaria virginiana[= *Polygonum virginianum*]	jumpseed	FAC	HP		
Polygonum achoreum	homeless knotweed	FACU	HA		
Polygonum erectum	erect knotweed	FACU	HA		
Polygonum tenue	slender knotweed	N	HA		
Caryophyllaceae					
Cerastium arvense ssp. *arvense*	field chickweed	N	HP		
Minuartia michauxii [= *Arenaria michauxii, Arenaria stricta*]	rock sandwort	N	HA / HP		
Minuartia patula	glade sandwort, Pitcher's stitchwort	N	HA		
Moehringia lateriflora [= *Arenaria lateriflora*]	blunt-leaved sandwort	FAC	HP		
Paronychia fastigiata var. *pumila* [= *P. montana*]	forked chickweed	N	HA		
Silene antirrhina	sleepy catchfly	N	HA		
Silene caroliniana ssp. *pensylvanica*	Pennsylvania catchfly, sticky catchfly	N	HP		
Silene stellata	starry campion	N	HP		
Stellaria longifolia	long-leaved stitchwort	FACW	HP		
Amaranthaceae					
Atriplex littoralis	seashore orach	N	HA		
Chenopodium album var. *missouriense*	lamb's quarters	N	HA		
Phytolaccaceae					
Phytolacca americana	pokeweed	FACU+	HP		

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Portulacaceae					
Claytonia virginica	spring-beauty	FAC	HP		
Portulaca oleracea	purslane	FAC	HA		
Saxifragaceae					
Heuchera pubescens	downy alum-root	N	HP		
Geraniaceae					
Geranium carolinianum	Carolina cranesbill, Carolina geranium	N	HA		
Geranium maculatum	wood geranium	FACU	HP		PA
Onagraceae					
Epilobium angustifolium [= *Chamerion angustifolium*]	fireweed	FAC	HP		
Epilobium leptophyllum	willow-herb	OBL	HP		
Gaura biennis	gaura, biennial bee-blossom	FACU	HA / HB		
Ludwigia alternifolia	seedbox, false loosestrife	FACW+	HP		PA
Ludwigia palustris	marsh-purslane, marsh seedbox, water-purslane	OBL	HP		
Oenothera biennis [= *Onagra biennis*]	common evening-primrose, biennial evening-primrose	FACU–	HB / HP		
Oenothera fruticosa ssp. *fruticosa*	sundrops, narrow-leaved evening-primrose	FAC	HP		
Oenothera fruticosa ssp. *glauca*	sundrops, narrow-leaved evening-primrose	FAC	HP		
Oenothera laciniata	cut-leaved evening-primrose	FACU–	HA		
Oenothera nutans	nodding evening-primrose	N	HB		
Oenothera parviflora	small-flowered evening-primrose	FACU–	HB		
Oenothera perennis [= *Kneiffia pumila*]	small sundrops, little evening-primrose	FAC–	HP		
Oenothera pilosella	sundrops, meadow evening-primrose	FAC	HP		

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Lythraceae					
Cuphea viscosissima [= *C. petiolata*]	blue waxweed, clammy cuphea	FAC–	HA		
Melastomaceae					
Rhexia virginica	meadow-beauty, handsome Harry	OBL	HP		
Violaceae					
Viola bicolor	field pansy	N	HA		
Viola cucullata	blue marsh violet	FACW+	HP		
Viola labradorica	American dog violet	FACW	HP		
Viola lanceolata var. *lanceolata*	lance-leaved violet	OBL	HP		
Viola palmata	early blue violet	N	HP		
Viola pedata	birdfoot violet	N	HP		
Viola primulifolia	primrose violet	FAC+	HP		
Viola sagittata var. *ovata*	ovate-leaved violet	FACW	HP		
Viola sagittata var. *sagittata*	arrow-leaved violet	FACW	HP		
Viola sororia	common blue violet	FAC–	HP		
Linum medium var. *texanum*	yellow flax	FACU	HP		
Linum virginianum	slender yellow flax	FACU	HP		
Hypericaceae					
Hypericum gentianoides	orange-grass, pineweed	UPL	HA		
Hypericum mutilum	dwarf St. John's-wort	FACW	HP		
Hypericum punctatum [= *H. maculatum*]	spotted St. John's-wort	FAC–	HP		PA
Hypericum pyramidatum [= *H. ascyron*]	great St. John's-wort	FAC	HP		PA
Hypericum sphaerocarpum	round-seeded St. John's-wort	FAC	HP		
Triadenum fraseri	Marsh St. Johns-wort	OBL	HP		

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Euphorbiaceae					
Acalypha gracilens	slender mercury	N	HA		
Acalypha rhomboidea	common three-seeded mercury	FACU–	HA		
Acalypha virginica	Virginia three-seeded mercury	FACU–	HA		
Croton capitatus	hogwort, wooly croton	N	HA		
Euphorbia corollata	flowering spurge	N	HP		
Euphorbia dentata [= *Poinsettia dentata*]	toothed spurge	N	HA		
Euphorbia nutans [= *Chamaesyce nutans*]	eyebane	FACU–	HA		
Euphorbia vermiculata [= *Chamaesyce vermiculata*]	hairy spurge	N	HA		
Oxalidaceae					
Oxalis dillenii ssp. *filipes*	southern yellow wood-sorrel	N	HP		
Oxalis grandis	great yellow wood-sorrel	N	HP		
Oxalis stricta	common yellow wood-sorrel	UPL	HP		
Polygalaceae					
Polygala sanguinea	field milkwort, rose milkwort	FACU	HA		
Polygala senega var. *latifolia*	Seneca snakeroot	FACU	HP		
Polygala verticillata var. *ambigua*	whorled milkwort	UPL	HA		
Polygala verticillata var. *isocycla*	whorled milkwort	UPL	HA		
Polygala verticillata var. *verticillata*	whorled milkwort	UPL	HA		
Fabaceae					
Baptisia tinctoria	wild indigo	N	HP		PA
Chamaecrista fasciculata [= *Cassia chamaecrista, C. fasciculata*]	partridge-pea, prairie senna	FACU	HA		PA
Chamaecrista nictitans [= *Cassia nictitans*]	wild sensitive-plant	FACU–	HA		
Crotalaria sagittalis	rattlebox	N	HA		

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Desmodium canescens [= *Meibomia canescens*]	hoary tick-trefoil	N	HP		
Desmodium marilandicum [= *Meibomia marylandica*]	Maryland tick-clover	N	HP		
Desmodium paniculatum	panicled tick-trefoil	UPL	HP		
Lespedeza capitata	round-headed bush-clover, round-headed lespedeza	FACU–	HP		NY, RI
Lespedeza hirta	hairy bush-clover, hairy lespedeza	N	HP		PA
Lespedeza procumbens	trailing bush-clover, trailing lespedeza	N	HP		
Lespedeza violacea	violet bush-clover, violet lespedeza	N	HP		
Lespedeza virginica	slender bush-clover, slender lespedeza	N	HP		
Senna hebecarpa	northern wild senna	FAC	HP		WV, VA
Tephrosia virginiana	goat's-rue	N	HP		
Vicia americana	purple vetch	N	VP		
Rosaceae					
Agrimonia gryposepala	tall hairy agrimony harvest-lice	FACU	HP		
Agrimonia rostellata	woodland agrimony	FACU	HP		
Agrimonia striata	roadside agrimony	FACU–	HP		
Aruncus dioicus	goat's-beard	FACU	HP		
Dalibarda repens	dewdrop	FAC	HP		
Fragaria virginiana	wild strawberry	FACU	HP		
Geum canadense	white avens	FACU	HP		PA
Geum laciniatum	herb-bennet, rough avens	FAC+	HP		PA
Geum rivale	water avens, purple avens	OBL	HP		
Potentilla arguta	tall cinquefoil	UPL	HP		
Potentilla canadensis	dwarf cinquefoil	N	HP		

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Potentilla norvegica ssp. *monspeliensis*	strawberry-weed	FACU	HA / HB		
Potentilla simplex	old-field cinquefoil	FACU–	HP		
Sanguisorba canadensis	American burnet	FACW+	HP		PA
Waldsteinia fragarioides	barren strawberry	N	HP		
Urticaceae					
Parietaria pensylvanica	pellitory	N	HA		
Brassicaceae					
Arabis glabra	towercress, tower mustard	N	HB		
Arabis lyrata [= *Arabidopsis lyrata*]	lyre-leaved rockcress	FACU	HB / HP		
Lepidium virginicum	poor-man's-pepper, wild pepper-grass	FACU–	HA / HB		
Rorippa palustris	marsh watercress, yellow watercress	OBL	HA / HB		
Cistaceae					
Helianthemum canadense	frostweed, long-branch frostweed	N	HP		
Lechea intermedia	large-pod pinweed	N	HP		
Lechea pulchella [= *L. leggettii*]	Leggett's pinweed	N	HP		
Lechea racemulosa	Illinois pinweed	N	HP		
Lechea villosa [= *L. mucronata*]	hairy pinweed	N	HP		
Balsaminaceae					
Impatiens capensis	jewelweed, spotted touch-me-not	FACW	HA		
Polemoniaceae					
Phlox maculata	wild sweet-william	FACW	HP		
Phlox subulata ssp. *subulata*	moss-pink, creeping phlox	N	HP		
Myrsinaceae					
Lysimachia ciliata [= *Steironema ciliata*]	fringed loosestrife	FACW	HP		

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Lysimachia lanceolata [= *Steironema lanceolatum*]	lance-leaved loosestrife	FAC	HP		
Ericaceae					
Chimaphila umbellata	pipsissewa, prince's-pine	N	HP		
Boraginaceae					
Hackelia virginiana	beggar's-lice, stickseed	FACU	HB		
Myosotis laxa	wild forget-me-not	OBL	HP		
Myosotis verna	spring forget-me-not, early scorpion-grass	FAC–	HA		
Phacelia dubia	scorpion-weed, small flowered phacelia	N	HA		
Phacelia purshii	Miami-mist	N	HA		
Rubiaceae					
Diodia teres	rough buttonweed	N	HA		
Galium aparine	stickywilly, bedstraw, cleavers, goosegrass	FACU	HA		
Galium boreale	northern bedstraw	FACU	HP		
Galium pilosum	hairy bedstraw, cleavers	N	HP		
Galium triflorum	sweet-scented bedstraw	FACU	HP		
Houstonia caerulea [= *Hedyotis caerulea*]	bluets, Quaker-ladies	FACU	HP		
Houstonia longifolia [= *Hedyotis nuttalliana, H. purpurea* var. *tenuifolia, Houstonia purpurea* var. *tenuifolia, H. tenuifolia*]	long-leaved bluets	N	HP		
Gentianaceae					
Bartonia virginica	bartonia	FACW	HA / HB		
Gentiana andrewsii	bottle gentian, prairie closed gentian	FACW	HP		
Gentiana clausa	meadow closed gentian, bottle gentian	FACW	HP		PA
Gentianella quinquefolia	stiff gentian, ague-weed	FAC	HA / HB		

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Gentianopsis crinita	eastern fringed gentian	OBL	HA / HB		
Sabatia angularis	common marsh-pink, rose-pink	FAC+	HA		
Apocynaceae					
Apocynum androsaemifolium	pink dogbane, spreading dogbane	N	HP		
Apocynum cannabinum [= *A. album*]	Indian-hemp	FACU	HP		PA
Asclepias amplexicaulis	blunt-leaved milkweed	N	HP		
Asclepias exaltata	poke milkweed, tall milkweed	FACU	HP		
Asclepias incarnata ssp. *incarnata*	swamp milkweed	OBL	HP		PA
Asclepias purpurascens	purple milkweed	FACU	HP		
Asclepias quadrifolia	four-leaved milkweed	N	HP		
Asclepias syriaca	common milkweed	FACU–	HP		PA
Asclepias tuberosa	butterfly-weed	N	HP		PA
Asclepias verticillata	whorled milkweed	N	HP		
Asclepias viridiflora [= *Acerates viridiflora*]	green milkweed	N	HP		
Plantaginaceae					
Gratiola neglecta	hedge hyssop, mud-hyssop	OBL	HA		
Linaria canadensis [= *Nuttallanthus canadensis*]	old-field toadflax	N	HA		
Lindernia dubia var. *anagallidea*	yellow-seeded false pimpernel	OBL	HA		
Penstemon digitalis	tall white beard-tongue	FAC	HP		PA
Penstemon hirsutus	northeastern beard-tongue	N	HP		
Plantago pusilla	dwarf plantain	UPL	HA		
Plantago rugelii	Rugel's plantain, broad-leaved plantain	FACU	HP		
Plantago virginica	dwarf plantain, pale-seeded plantain	UPL	HA / HB		
Veronica officinalis	common speedwell, gypsyweed	FACU–	HP		

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Veronica peregrina ssp. *peregrina*	neckweed, purslane speedwell	FACU–	HA		
Veronica peregrina ssp. *xalapensis*	neckweed, purslane speedwell	FACU–	HA		
Veronicastrum virginicum	Culver's-root	FACU	HP		PA
Scrophulariaceae					
Scrophularia lanceolata	lanceleaf figwort	FACU+	HP		
Scrophularia marilandica	eastern figwort, carpenter's-square	FACU–	HP		
Orobanchaceae					
Agalinis purpurea [= *Gerardia purpurea*]	purple false-foxglove	FACW–	HA		
Agalinis tenuifolia [= *Gerardia tenuifolia*]	slender false-foxglove	FAC	HA		
Aureolaria pedicularia	cut-leaf false-foxglove	N	HA		
Melampyrum lineare var. *americanum*	cow-wheat	FACU	HA		
Verbenaceae					
Verbena hastata	blue vervain, simpler's-joy	FACW+	HP		PA
Verbena simplex	narrow-leaved vervain	N	HP		
Verbena urticifolia var. *urticifolia*	white vervain	FACU	HA / HP		PA
Lamiaceae					
Agastache nepetoides	yellow giant-hyssop	FACU	HP		
Agastache scrophulariifolia	purple giant-hyssop	N	HP		
Calamintha arkansana [= *Clinopodium arkansanum*]	calamint	FACU	HP		
Cunila origanoides	common dittany, stone-mint	N	HP		
Hedeoma pulegioides	American pennyroyal, pudding-grass	N	HA		
Lycopus americanus	water-horehound	OBL	HP		
Lycopus uniflorus	bugleweed, water-horehound	OBL	HP		
Mentha arvensis [= *M. canadensis*]	field mint	FACW	HP		

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Monarda clinopodia	white bergamot, basil bee-balm	N	HP		
Monarda fistulosa [= *M. mollis*]	horsemint, wild bergamot	UPL	HP		
Physostegia virginiana	false dragonhead	FAC+	HP		
Prunella vulgaris ssp. *lanceolata*	heal-all, self-heal	FACU+	HP		
Pycnanthemum incanum	hoary mountain-mint	N	HP		MD
Pycnanthemum muticum	short-toothed mountain-mint, clustered mountain-mint	FACW	HP		PA
Pycnanthemum tenuifolium	narrow-leaved mountain-mint, slender mountain-mint	FACW	HP		
Pycnanthemum verticillatum var. *verticillatum*	whorled mountain-mint	FAC	HP		
Pycnanthemum virginianum	Virginia mountain-mint	FAC	HP		PA
Salvia lyrata	lyre-leaved sage	UPL	HP		
Salvia reflexa	lance-leaved sage	N	HA		
Scutellaria galericulata	common skullcap	OBL	HP		
Scutellaria incana	downy skullcap	N	HP		
Scutellaria integrifolia	hyssop skullcup	FACW	HP		
Scutellaria lateriflora	mad-dog skullcap	FACW+	HP		
Scutellaria leonardii	small skullcap	N	HP		
Stachys tenuifolia	creeping hedge-nettle	FACW+	HP		
Teucrium canadense var. *virginicum*	wild germander, wood-sage	FACW	HP		
Trichostema brachiatum	false pennyroyal	N	HP		
Trichostema dichotomum	blue-curls	N	HA		
Phrymaceae					
Mimulus alatus	winged monkey-flower	OBL	HP		
Mimulus ringens	Allegheny monkey-flower	OBL	HP		PA

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Convolvulaceae					
Ipomoea pandurata	man-of-the-earth, wild potato-vine	FACU	VP		
Solanaceae					
Physalis heterophylla	clammy ground-cherry	N	HP		
Physalis pubescens var. *integrifolia*	hairy ground-cherry	FACU–	HA		
Physalis subglabrata	long-leaved ground-cherry	N	HP		
Solanum americanum	black nightshade	FACU–	HA		
Solanum carolinense	horse-nettle	UPL	HP		
Araliaceae					
Aralia hispida	bristly sarsaparilla	N	HP		
Hydrocotyle americana	marsh pennywort, navelwort	OBL	HP		
Hydrocotyle ranunculoides	floating pennywort	OBL	HP		
Apiaceae					
Angelica atropurpurea	purple-stemmed angelica	OBL	HP		
Angelica venenosa [= *A. villosa*]	deadly angelica, hairy angelica	N	HP		
Cicuta bulbifera	water-hemlock	OBL	HP		
Cicuta maculata var. *maculata*	beaver-poison, musquash-root, spotted cowbane	OBL	HP		
Heracleum lanatum [= *H. maximum*]	cow-parsnip	FACU–	HP		
Osmorhiza claytonii [= *Washingtonia claytonii*]	sweet-cicely	FACU–	HP		
Sanicula canadensis var. *canadensis*	Canadian sanicle, snake root	UPL	HB		
Sanicula canadensis var. *grandis*	Canadian sanicle, snake root	UPL	HB		
Sanicula marilandica	Black snake root, Black sanicle	UPL	HP		
Sium suave	water-parsnip	OBL	HP		
Thaspium barbinode	meadow-parsnip	UPL	HP		

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Thaspium trifoliatum var. *flavum*	meadow-parsnip	N	HP		
Zizia aptera	golden-alexander, meadow zizia	FAC	HP		
Zizia aurea	golden-alexander, golden zizia	FAC	HP		PA
Campanulaceae					
Campanula aparinoides	marsh bellflower	OBL	HP		
Lobelia cardinalis	cardinal-flower	FACW+	HP		PA
Lobelia inflata	Indian-tobacco	FACU	HA		
Lobelia siphilitica	great blue lobelia	FACW+	HP		PA
Lobelia spicata var. *leptostachys*	spiked lobelia	FAC	HP		
Lobelia spicata var. *scaposa*	spiked lobelia	FAC–	HP		
Lobelia spicata var. *spicata*	spiked lobelia	FAC–	HP		
Triodanis perfoliata var. *perfoliata*	Venus's looking-glass	FAC	HA		
Asteraceae					
Ageratina altissima var. *altissima* [= *Eupatorium rugosum*]	common white snakeroot	N	HP		
Ambrosia artemisiifolia	common ragweed	FACU	HA		
Ambrosia psilostachya	western ragweed	FACU–	HP		
Ambrosia trifida	giant ragweed	FAC	HA		
Anaphalis margaritacea	pearly everlasting	N	HP		
Antennaria howellii [= *A. neglecta* var. *attenuata, A. neglecta* var. *neodioica, A. neodioica*]	Howell's pussytoe	N	HP		
Antennaria neglecta	overlooked pussytoe	UPL	HP		
Antennaria parlinii [= *A. brainerdii, A. fallax, A. munda, A. plantaginifolia* var. *ambigens*]	Parlin's pussytoe	N	HP		

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Antennaria plantaginifolia	plantain-leaved pussytoe	N	HP		
Arnoglossum atriplicifolium [= *Cacalia atriplicifolia, Mesadenia atriplicifolia*]	pale Indian-plantain	N	HP		
Bidens bipinnata	spanish needles	N	HA		
Bidens cernua	bur-marigold, stick-tight	OBL	HA		PA
Bidens connata	beggar-ticks, stick-tight	FACW+	HA		
Bidens frondosa	devil's beggar-ticks, stick-tights	FACW	HA		PA
Bidens vulgata	beggar-ticks, stick-tights	N	HA		
Brickellia eupatorioides [= *Kuhnia eupatorioides*]	false boneset	N	HP		
Cirsium altissimum [= *Carduus altissimus*]	tall thistle	N	HB / HP		
Cirsium discolor [= *Carduus discolor*]	field thistle	UPL	HB / HP		
Cirsium muticum	swamp thistle	OBL	HB		
Cirsium pumilum [= *Carduus odoratus*]	pasture thistle	N	HB		
Conyza canadensis var. *canadensis*	horseweed	UPL	HA		
Coreopsis tripteris	tall tickseed	FAC	HP		PA, OH
Doellingeria infirma [= *Aster infirmus*]	flat-topped white aster	N	HP		
Doellingeria umbellata [= *Aster umbellatus*]	flat-topped white aster	FACW	HP		PA
Eclipta prostrata	yerba-de-tajo	FAC	HA		
Erechtites hieraciifolius [= *E. hieraciifolia*]	fireweed, pilewort	FACU	HA		
Erigeron annuus	daisy fleabane	FACU	HA / HB		
Erigeron philadelphicus	daisy fleabane	FACU	HP		
Erigeron pulchellus	robin's-plantain	FACU	HB / HP		
Erigeron strigosus var. *strigosus* [= *E. ramosus*]	daisy fleabane, whitetop	FACU+	HA / HB		

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Eupatorium altissimum [= *E. rugosum* var. *tomentellum*]	tall eupatorium, tall thoroughwort	N	HP		
Eupatorium hyssopifolium	hyssop-leaved eupatorium, hyssop-leaved thoroughwort	N	HP		
Eupatorium perfoliatum	common boneset	FACW+	HP		PA
Eupatorium pilosum	ragged eupatorium, rough boneset	FACW	HP		
Eupatorium sessilifolium	upland eupatorium, upland boneset	N	HP		
Euthamia graminifolia [= *Solidago graminifolia*]	grass-leaved goldenrod, flat-topped goldenrod	FAC	HP		PA
Eutrochium fistulosum [= *Eupatorium fistulosum, Eupatoriadelphus fistulosus*]	hollow-stemmed joe-pye-weed, trumpetweed	FACW	HP		PA
Eutrochium purpureum [= *Eupatorium purpureum*]	sweet-scented joe-pye-weed	N	HP		WV
Gamochaeta purpurea var. *purpurea* [= *Gnaphalium purpureum*]	purple cudweed	N	HA / HB		
Gnaphalium uliginosum	low cudweed	FAC	HA		
Hasteola suaveolens [= *Cacalia suaveolens, Synosma suaveolens*]	sweet-scented Indian-plantain	N	HP		
Helenium autumnale	common sneezeweed	FACW+	HP		PA, VA
Helianthus decapetalus [= *H. trachelifolius*]	thin-leaved sunflower	FACU	HP		PA
Helianthus divaricatus	rough sunflower, woodland sunflower	N	HP		PA
Helianthus giganteus	swamp sunflower	FACW	HP		
Helianthus strumosus	rough-leaved sunflower	N	HP		
Heliopsis helianthoides	ox-eye	N	HP		PA
Hieracium scabrum	rough hawkweed	N	HP		
Krigia biflora	dwarf dandelion, two-flowered cynthia	FACW	HP		
Krigia virginica	Virginia dwarf dandelion	UPL	HA		

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Lactuca biennis	tall blue lettuce	FACU	HA / HB		
Lactuca canadensis	wild lettuce, Canada lettuce	FACU–	HA / HB		
Lactuca floridana var. *floridana*	woodland lettuce	FACU–	HA / HB		
Lactuca floridana var. *villosa*	woodland lettuce	FACU–	HA / HB		
Liatris spicata var. *spicata* [= *Laciniaria spicata*]	dense blazing-star	FAC+	HP		
Packera aurea [= *Senecio aureus*]	golden ragwort	FACW	HP		
Packera obovata [= *Senecio obovatus*]	round-leaved ragwort, squaw-weed	FACU–	HP		
Packera paupercula [= *Senecio crawfordii, S. pauperculus*]	balsam ragwort	FAC	HP		
Polymnia canadensis	leaf-cup	N	HP		
Prenanthes alba [= *Nabalus albus*]	white rattlesnake-root	FACU	HP		
Prenanthes trifoliolata [= *Nabalus trifoliatus*]	gall-of-the-earth	N	HP		
Pseudognaphalium macounii [= *Gnaphalium macounii, G. viscosum*]	clammy cudweed, western cudweed	N	HB		
Pseudognaphalium obtusifolium [= *Gnaphalium obtusifolium*]	fragrant cudweed, rabbit-tobacco	N	HA / HB		
Rudbeckia fulgida var. *speciosa*	orange coneflower	FAC	HP		
Rudbeckia hirta var. *hirta*	black-eyed-susan	FACU–	HB / HP		NC
Rudbeckia hirta var. *pulcherrima*	black-eyed-susan	FACU–	HB / HP		
Rudbeckia laciniata var. *laciniata*	cutleaf coneflower	FACW	HP		
Rudbeckia triloba var. *triloba*	three-lobed coneflower	FACU	HP		WV
Sericocarpus asteroides [= *Aster paternus*]	white-topped aster	N	HP		
Silphium asteriscus var. *trifoliatum* [= *S. trifoliatum*]	whorled rosinweed	N	HP		PA

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Solidago altissima [= *S. canadensis var. scabra*]	late goldenrod	FACU	HP		
Solidago arguta var. *arguta*	forest goldenrod	N	HP		
Solidago bicolor	silver-rod, white goldenrod	N	HP		PA
Solidago canadensis var. *canadensis*	Canada goldenrod	FACU	HP		
Solidago canadensis var. *hargeri*	Canada goldenrod	FACU	HP		
Solidago gigantea var. *gigantea*	smooth goldenrod	FACW	HP		
Solidago gigantea var. *serotina*	smooth goldenrod	FACW	HP		
Solidago hispida	hairy goldenrod	N	HP		
Solidago juncea	early goldenrod	N	HP		PA
Solidago lepida [= *S. canadensis var. salebrosa*]	Canada goldenrod	FACU	HP		
Solidago nemoralis	gray goldenrod	N	HP		PA
Solidago puberula	downy goldenrod	FACU–	HP		
Solidago rugosa ssp. *aspera* var. *aspera*	wrinkle-leaf goldenrod	FAC	HP		
Solidago rugosa ssp. *rugosa* var. *rugosa*	wrinkle-leaf goldenrod	FAC	HP		PA
Solidago rugosa ssp. *rugosa* var. *sphagnophila*	wrinkle-leaf goldenrod	FAC	HP		
Solidago squarrosa	ragged goldenrod, stout goldenrod	N	HP		
Solidago ulmifolia var. *ulmifolia*	elm-leaved goldenrod	N	HP		
Symphyotrichum cordifolium [= *Aster cordifolius, A. sagittifolius*]	blue wood aster	N	HP		PA
Symphyotrichum laeve var. *concinnum* [= *Aster concinnus, A. laevis var. concinnus*]	smooth blue aster	N	HP		
Symphyotrichum laeve var. *laeve* [= *Aster laevis var. laevis*]	smooth blue aster	N	HP		PA

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Symphyotrichum lanceolatum ssp. *lanceolatum* var. *interior* [= *Aster lanceolatus ssp. interior*]	eastern lined aster	N	HP		
Symphyotrichum lanceolatum ssp. *lanceolatum* var. *lanceolatum* [= *Aster lanceolatus, A. paniculatus, Aster simplex*]	panicled aster	N	HP		
Symphyotrichum lateriflorum [= *Aster lateriflorus, A. vimineus* (in part)]	calico aster	FACW–	HP		PA
Symphyotrichum lowrieanum [= *Aster cordifolius ssp. laevigatus, A. lowrieanus*]	smooth heart-leaved aster	N	HP		
Symphyotrichum novae-angliae [= *Aster novae-angliae*]	New England aster	FAC	HP		PA
Symphyotrichum patens [= *Aster patens*]	late purple aster, clasping aster	N	HP		
Symphyotrichum phlogifolium [= *Aster patens var. phlogifolius, A. phlogifolius*]	late purple aster	N	HP		
Symphyotrichum pilosum var. *pilosum* [= *Aster ericoides var. pilosus, A. pilosus*]	heath aster	UPL	HP		
Symphyotrichum puniceum [= *Aster puniceus ssp. puniceus*]	purple-stemmed aster	OBL	HP		PA
Symphyotrichum racemosum [= *Aster fragilis, A. racemosus, A. vimineus* (in part)]	small white aster	FAC	HP		
Symphyotrichum undulatum [= *Aster undulatus*]	clasping heart-leaved aster	N	HP		
Symphyotrichum urophyllum [= *Aster hirtellus, A. sagittifolius, A. urophyllus*]	arrow-leaved aster	N	HP		PA
Verbesina alternifolia	wingstem	FAC	HP		PA
Vernonia gigantea [= *V. altissima*]	giant ironweed	FAC	HP		PA
Vernonia noveboracensis	New York ironweed	FACW+	HP		PA

family / scientific name	common name(s)	wetland status	growth form	C_3 or C_4 (grasses)	Ernst Seeds
Xanthium strumarium	common cocklebur	FAC	HA		
Caprifoliaceae					
Triosteum perfoliatum	horse-gentian	N	HP		
Valerianaceae					
Valerianella chenopodiifolia	goose-foot corn-salad	N	HP		
Valerianella umbilicata [= *V. intermedia, V. patellaria*]	navel corn-salad	FAC	HA		

Appendix C. **Woody plant species commonly inhabiting long-lived grasslands, meadows, and savannas in Pennsylvania**

(*N* = 75). Endangered, threatened, and rare species of special concern in Pennsylvania are not listed here; see Appendix D. Taxonomy, wetland status[1], and growth form[2] are from Rhoads and Block (2007).

family / scientific name	common name(s)	wetland status	growth form
CONIFERS			
Pinaceae			
Pinus rigida	pitch pine	FACU	TE
Pinus virginiana	Virginia pine	N	TE
Cupressaceae			
Juniperus virginiana	eastern red-cedar	FACU	TE
FLOWERING PLANTS			
Smilacaceae			
Smilax glauca	catbrier, greenbrier	FACU	VW
Smilax hispida [= *S. tamnoides*]	bristly greenbrier	N	VW
Smilax rotundifolia	bullbrier, common greenbrier	FAC	VW
Lauraceae			
Sassafras albidum	sassafras	FACU–	TD

[1] Wetland status codes:

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
N	not rated

[2] Growth-form codes:

SD	deciduous shrub
SE	evergreen shrub
TD	deciduous tree
TE	evergreen tree
VW	woody vine

family / scientific name	common name(s)	wetland status	growth form
Vitaceae			
Parthenocissus inserta [= *P. quinquefolia* (in part)	grape woodbine	N	VW
Parthenocissus quinquefolia	Virginia-creeper, woodbine	FACU	VW
Vitis vulpina	frost grape	FAC	VW
Celastraceae			
Celastrus scandens	American bittersweet	FACU–	VW
Salicaceae			
Populus tremuloides	quaking aspen	N	TD
Salix eriocephala	diamond willow	FACW+	SD
Salix exigua [= *S. interior*]	sandbar willow	OBL	SD
Salix humilis var. *humilis*	upland willow	FACU	SD
Salix humilis var. *tristis*	dwarf upland willow, sage willow	FACU	SD
Salix nigra	black willow	FACW+	TD
Salix petiolaris	slender willow	FACW+	SD
Hypericaceae			
Hypericum prolificum	shrubby St. John's-wort	FACU	SD
Fagaceae			
Quercus ilicifolia	scrub oak, bear oak	N	SD
Quercus marilandica	blackjack oak	N	TD
Quercus prinoides	dwarf chestnut oak	N	SD
Quercus stellata	post oak	UPL	TD
Myricaceae			
Comptonia peregrina	sweet-fern	N	SD
Myrica pensylvanica [= *Morella pensylvanica*]	bayberry	FAC	SD

family / scientific name	common name(s)	wetland status	growth form
Betulaceae			
Betula populifolia	gray birch	FAC	TD
Rosaceae			
Amelanchier laevis	smooth serviceberry, smooth shadbush	N	TD
Amelanchier stolonifera	low juneberry, low shadbush	FACU	SD
Crataegus calpodendron	pear hawthorn, blackthorn hawthorn	N	SD / TD
Crataegus chrysocarpa	fireberry hawthorn	N	SD / TD
Crataegus coccinea	red-fruited hawthorn	N	SD / TD
Crataegus crus-galli	cockspur hawthorn	FACU	SD / TD
Crataegus intricata [= *C. intricata*]	Biltmore hawthorn	N	SD / TD
Crataegus macrosperma [= *C. flabellata*]	fanleaf hawthorn	N	SD / TD
Crataegus punctata	dotted hawthorn, white hawthorn	N	TD
Crataegus succulenta	long-spined hawthorn, fleshy hawthorn	N	TD
Malus coronaria	sweet crabapple	N	TD
Photinia melanocarpa [= *Aronia melanocarpa*]	black chokeberry	FAC	SD
Physocarpus opulifolius	ninebark	FACW–	SD
Prunus americana	wild plum	FACU–	SD / TD
Prunus angustifolia	Chickasaw plum	N	TD / SD
Prunus pensylvanica	pin cherry, fire cherry	FACU–	TD
Rosa carolina	pasture rose	UPL	SD
Rubus allegheniensis	common blackberry	FACU–	SD
Rubus flagellaris	prickly dewberry, northern dewberry	FACU	VW
Rubus hispidus	swamp dewberry	FACW	VW
Rubus idaeus var. *strigosus*	red raspberry	FAC–	SD

family / scientific name	common name(s)	wetland status	growth form
Rubus pensilvanicus	blackberry	N	SD
Spiraea alba	meadow-sweet	FACW+	SD
Spiraea latifolia [= *S. alba* var. *latifolia*]	meadow-sweet	FAC+	SD
Spiraea tomentosa	hardhack, steeple-bush	FACW–	SD
Rhamnaceae			
Ceanothus americanus	New Jersey tea	N	SD
Rutaceae			
Zanthoxylum americanum	prickly-ash	FACU	SD
Anacardiaceae			
Rhus aromatica var. *aromatica*	fragrant sumac, squawbush	N	SD
Rhus copallina var. *copallina*	shining sumac, winged sumac	N	SD
Rhus copallina var. *latifolia*	shining sumac, dwarf sumac	N	SD
Rhus glabra	smooth sumac	N	SD
Rhus typhina	staghorn sumac	N	SD
Toxicodendron radicans	poison-ivy	FAC	VW
Cornaceae			
Cornus amomum ssp. *amomum*	kinnikinik, red-willow	FACW	SD
Cornus racemosa	silky dogwood	FAC–	SD
Cornus sericea	red-osier dogwood	FACW+	SD
Ebenaceae			
Diospyros virginiana	persimmon	FAC–	TD
Ericaceae			
Rhododendron canadense	rhodora	FACW	SD
Vaccinium angustifolium	low sweet blueberry	FACU–	SD

family / scientific name	common name(s)	wetland status	growth form
Bignoniaceae			
Campsis radicans	trumpet-vine, trumpet-creeper	FAC	VW
Araliaceae			
Aralia spinosa	Hercules'-club	FAC	TD
Adoxaceae			
Sambucus canadensis [= *S. nigra* ssp. *canadensis*]	American elder	FACW	SD
Viburnum lentago	nannyberry, sheepberry	FAC	SD
Viburnum prunifolium	black-haw	FACU	SD / TD
Viburnum rafinesquianum	downy arrow-wood	N	SD
Viburnum recognitum	northern arrow-wood	FACW–	SD
Caprifoliaceae			
Lonicera sempervirens	trumpet honeysuckle	FACU	VW
Symphoricarpos albus var. *albus*	snowberry	FACU–	SD
Symphoricarpos orbiculatus	coralberry, Indian-currant	UPL	SD

Appendix D. **Endangered, threatened, and rare vascular plant species native to grasslands, meadows, and savannas in Pennsylvania**

(N = 259). Taxonomy, status[1], and growth form[2] are from Rhoads and Block (2007).

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
CLUBMOSSES AND SPIKEMOSSES				
Lycopodiaceae				
Lycopodiella alopecuroides	foxtail bog clubmoss	PE	HP	
FERNS AND HORSETAILS				
Ophioglossaceae				
Ophioglossum vulgatum	southern adder's-tongue	PR	HP	
CONIFERS				
Cupressaceae				
Juniperus communis	common juniper	TU	SE	
FLOWERING PLANTS				
Melanthiaceae				
Stenanthium gramineum	featherbells	TU	HP	

[1] Pennsylvania status codes:

PX	extirpated in the state
PE	endangered in the state
PT	threatened in the state
PR	rare in the state
TU	status tentatively undetermined and under study

[2] Growth-form codes:

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

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Orchidaceae				
Cypripedium candidum	small white lady's-slipper	PX	HP	
Malaxis bayardii	adder's-mouth	PE	HP	
Platanthera ciliaris	yellow fringed-orchid	PT	HP	
Platanthera cristata	crested fringed-orchid	PX	HP	
Platanthera dilatata var. *dilatata*	tall white bog-orchid	PE	HP	
Platanthera huronensis	tall green bog-orchid	PE	HP	
Platanthera leucophaea	eastern prairie fringed-orchid	PX	HP	
Platanthera peramoena	purple fringeless orchid	PT	HP	
Spiranthes casei	Case's ladies'-tresses	PE	HP	
Spiranthes lucida	shining ladies'-tresses	TU	HP	
Spiranthes magnicamporum	Great Plains ladies'-tresses	PX	HP	
Spiranthes tuberosa	slender ladies'-tresses	PX	HP	
Spiranthes vernalis	spring ladies'-tresses	PE	HP	
Iridaceae				
Iris prismatica	slender blue flag	PE	HP	
Sisyrinchium albidum	white blue-eyed-grass	PX	HP	
Sisyrinchium atlanticum	eastern blue-eyed-grass	PE	HP	
Sisyrinchium fuscatum	sand blue-eyed-grass	PX	HP	
Juncaceae				
Juncus alpinoarticulatus ssp. *nodulosus*	alpine rush	PT	HP	
Juncus biflorus	grass rush	PT	HP	
Juncus brachycarpus	short-fruited rush	PE	HP	
Juncus dichotomus	forked rush	PE	HP	
Luzula bulbosa	woodrush	PE	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Cyperaceae				
Carex adusta	crowded sedge	PX	HP	
Carex alata	broad-winged sedge	PT	HP	
Carex atherodes	awned sedge	PE	HP	
Carex bebbii	Bebb's sedge	PE	HP	
Carex bicknellii	Bicknell's sedge	PE	HP	
Carex brevior	shortbeak sedge	TU	HP	
Carex bullata	bull sedge	PE	HP	
Carex buxbaumii	brown sedge	PR	HP	
Carex crawfordii	Crawford's sedge	PE	HP	
Carex cryptolepis	northeastern sedge	PE	HP	
Carex flava	yellow sedge	PT	HP	
Carex haydenii	cloud sedge	PT	HP	
Carex longii	Long's sedge	TU	HP	
Carex lupuliformis	false hop sedge	TU	HP	
Carex meadii	Mead's sedge	PE	HP	
Carex mitchelliana	Mitchell's sedge	PE	HP	
Carex ormostachya	spike sedge	TU	HP	
Carex polymorpha	variable sedge	PT	HP	
Carex prairea	prairie sedge	PT	HP	
Carex richardsonii	Richardson's sedge	PE	HP	
Carex shortiana	Short's sedge	PR	HP	
Carex sprengelii	Sprengel's sedge	PR	HP	
Carex tetanica	Wood's sedge	PT	HP	
Carex wiegandii	Wiegand's sedge	PT	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Cyperus houghtonii	Houghton's flatsedge	PE	HP	
Cyperus lancastriensis	umbrella sedge	TU	HP	
Cyperus schweinitzii	Schweinitz's flatsedge	PR	HP	
Eleocharis geniculata	Canada spike-rush	PE	HA	
Eleocharis tenuis var. *verrucosa*	slender spike-rush	PE	HP	
Eleocharis tricostata	three-ribbed spike-rush	PX	HP	
Eriophorum gracile	slender cotton-grass	PE	HP	
Eriophorum viridicarinatum	thin-leaved cotton-grass	PT	HP	
Fimbristylis annua	annual fimbry	PT	HA	
Lipocarpha micrantha	common hemicarpa	PE	HA	
Rhynchospora recognita	beak-rush	TU	HP	
Scirpus pedicellatus	wool-grass, stalked bulrush	PT	HP	
Scleria muhlenbergii	reticulated nut-rush	PE	HA / HP	
Scleria pauciflora	few-flowered nut-rush	PT	HP	
Scleria triglomerata	whip-grass, nut-rush	TU	HP	
Scleria verticillata	whorled nut-rush	PE	HA	
Poaceae				
Alopecurus aequalis	short-awned foxtail	TU	HP	C_3
Andropogon glomeratus	broom-sedge	PR	HP	C_4
Andropogon gyrans	Elliott's beardgrass	PR	HP	C_4
Aristida dichotoma var. *curtissii*	povertygrass	TU	HA	C_4
Aristida purpurascens	arrow-feather, three-awned grass	PT	HP	C_4
Bouteloua curtipendula	side-oats grama, tall grama	PT	HP	C_4
Deschampsia cespitosa	tufted hairgrass	TU	HP	C_3

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Dichanthelium annulum [= *D. dichotomum* (in part)]	annulus panic grass	PT	HP	C_3
Dichanthelium commonsianum var. *commonsianum* [= *D. ovale* var. *addisonii*]	cloaked panicgrass	PX	HP	C_3
Dichanthelium laxiflorum	panic grass	PE	HP	C_3
Dichanthelium scoparium	velvety panic grass	PE	HP	C_3
Dichanthelium spretum	panic grass	PE	HP	C_3
Dichanthelium villosissimum	long-haired panic grass	TU	HP	C_3
Elymus trachycaulus	slender wheatgrass	TU	HP	C_3
Festuca paradoxa	cluster fescue	PE	HP	C_3
Gymnopogon ambiguus	broad-leaved beardgrass	PX	HP	C_4
Hesperostipa spartea	needlegrass, porcupine grass	TU	HP	C_3
Hierochloe odorata [= *H. hirta* ssp. *arctica*]	vanilla sweetgrass	PE	HP	C_3
Hordeum pusillum	little-barley	PX	HA	C_3
Muhlenbergia capillaris	hairgrass, short muhly	PX	HP	C_4
Muhlenbergia uniflora	fall dropseed muhly	PT	HP	C_4
Panicum flexile	old witchgrass	TU	HA	C_4
Panicum longifolium [= *P. rigidulum* var. *pubescens*]	long-leaved panic grass	PE	HP	C_4
Paspalum setaceum var. *muhlenbergii*	slender beadgrass	TU	HP	C_4
Paspalum setaceum var. *setaceum*	slender beadgrass	TU	HP	C_4
Piptatherum pungens	slender mountain ricegrass	PE	HP	C_3
Piptochaetium avenaceum	black oatgrass	PE	HP	C_3
Schizachyrium scoparium var. *littorale* [= *S. littorale*]	seaside bluestem	PR	HP	C_4
Sporobolus heterolepis	prairie dropseed	PE	HP	C_4

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Triplasis purpurea	purple sandgrass	PE	HA	C_4
Tripsacum dactyloides	gammagrass	PE	HP	C_3
Trisetum spicatum	oatgrass	PE	HP	C_3
Commelinaceae				
Commelina virginica	Virginia dayflower	PX	HP	
Ranunculaceae				
Anemone cylindrica	thimbleweed, long-headed anemone	PE	HP	
Ranunculus flammula var. *reptans*	creeping spearwort	PX	HP	
Trollius laxus	spreading globe-flower	PE	HP	
Papaveraceae				
Corydalis aurea	golden corydalis	PE	HB	
Polygonaceae				
Persicaria careyi [= *Polygonum careyi*]	pinkweed, smartweed	PE	HA	
Polygonella articulata	jointweed	PE	HA	
Polygonum ramosissimum ssp. *ramosissimum*	bushy knotweed	PX	HA	
Rumex hastatulus	heart sorrel, red sorrel	PX	HP	
Caryophyllaceae				
Cerastium velutinum var. *villosissimum* [= *C. arvense* ssp. *velutinum* var. *villosum*]	serpentine barrens chickweed	PE	HP	
Paronychia fastigiata var. *nuttallii*	whitlow-wort	PE	HA	
Amaranthaceae				
Chenopodium capitatum	Indian-paint, strawberry-blite	TU	HA	
Cactaceae				
Opuntia humifusa	eastern prickly-pear cactus	PR	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Portulacaceae				
Phemeranthus teretifolius	round-leaved fameflower	PT	HP	
Crassulaceae				
Sedum telephioides [= *Hylotelephium telephioides*]	Allegheny stonecrop	PR	HP	
Geraniaceae				
Geranium bicknellii	Bicknell's cranesbill	PE	HA / HB	
Onagraceae				
Epilobium strictum	downy willow-herb	PR	HP	
Ludwigia polycarpa	false loosestrife, seedbox	PE	HP	
Oenothera argillicola	shale-barren evening-primrose	PT	HB / HP	
Oenothera oakesiana	evening-primrose	TU	HB	
Lythraceae				
Ammannia coccinea	tooth cup, valley redstem	PT	HA	
Lythrum alatum	winged loosestrife	PE	HP	
Rotala ramosior	tooth cup, lowland rotala	PR	HA	
Parnassiaceae				
Parnassia glauca	grass-of-parnassus	PE	HP	
Salicaceae				
Salix candida	hoary willow, sage-leaved willow	PE	SD	
Salix caroliniana	Carolina willow	PE	TD	
Salix serissima	autumn willow	PT	SD	
Linaceae				
Linum intercursum	sandplain wild flax	PE	HP	
Linum sulcatum	grooved yellow flax	PE	HA	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Hypericaceae				
Hypericum densiflorum	bushy St. John's-wort	PR	SD	
Hypericum drummondii	nits-and-lice	PX	HA	
Hypericum stragulum [= *H. hypericoides* ssp. *multicaule*]	St. Andrew's-cross	TU	SD	
Phyllanthaceae				
Phyllanthus caroliniensis	Carolina leaf-flower	PE	HA	
Polygalaceae				
Polygala cruciata	cross-leaved milkwort	PE	HA	
Polygala curtissii	Curtis's milkwort	PE	HA	
Polygala incarnata	pink milkwort	PE	HA	
Polygala polygama	bitter milkwort, racemed milkwort	PE	HB	
Fabaceae				
Astragalus canadensis	milk-vetch	TU	HP	
Astragalus neglectus	Cooper's milk-vetch	PE	HP	
Baptisia australis	blue false-indigo	TU	HP	
Desmodium laevigatum	smooth tick-clover	TU	HP	
Desmodium nuttallii	Nuttall's tick-trefoil	TU	HP	
Desmodium viridiflorum	velvety tick-trefoil	TU	HP	
Lathyrus japonicus var. *glaber*	beach pea	PT	HP	
Lathyrus palustris	marsh pea, vetchling	PE	VP	
Lathyrus venosus	veiny pea, veiny vetchling	TU	HP	
Lespedeza angustifolia	narrow-leaved bush-clover	PE	HP	
Lespedeza stuevei	tall bush-clover	PX	HP	
Lupinus perennis	blue lupine	PR	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Phaseolus polystachios	wild bean, thicket bean	TU	VP	
Senna marilandica	southern wild senna	PE	HP	
Strophostyles umbellata	wild bean, pink fuzzy-bean	PE	VP	
Stylosanthes biflora	pencil-flower	PE	HP	
Trifolium reflexum	buffalo clover	PX	HA / HB	
Rosaceae				
Amelanchier humilis	low juneberry, low serviceberry	PE	SD	
Amelanchier obovalis	coastal juneberry, coastal shadbush	PE	SD	
Amelanchier sanguinea	roundleaf serviceberry, roundleaf shadbush	PE	SD	
Crataegus dilatata	broadleaf hawthorn	TU	TD	
Crataegus mollis	downy hawthorn	TU	TD	
Filipendula rubra	queen-of-the-prairie	TU	HP	
Potentilla anserina [= *Argentina anserina*]	silverweed	PR	HP	
Potentilla paradoxa	bushy cinquefoil	PE	HA / HB	
Prunus alleghaniensis	Allegheny plum	PT	TD	
Prunus maritima	beach plum	PE	SD	
Prunus pumila var. *depressa*	sand cherry	PE	SD	
Rosa virginiana	wild rose, pasture rose	TU	SD	
Rubus cuneifolius	sand blackberry	PE	SD	
Rhamnaceae				
Rhamnus lanceolata	lanceolate buckthorn	PE	SD	
Brassicaceae				
Cardamine pratensis	cuckoo-flower, lady's-smock	TU	HP	
Cistaceae				
Helianthemum bicknellii	Bicknell's hoary rockrose	PE	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Helianthemum propinquum	low frostweed	TU	HP	
Lechea minor	thyme-leaved pinweed	TU	HP	
Rutaceae				
Ptelea trifoliata	hoptree, wafer-ash	PT	SD	
Polemoniaceae				
Phlox ovata [= *P. latifolia*]	mountain phlox	PE	HP	
Phlox pilosa	downy phlox, prairie phlox	PE	HP	
Phlox subulata ssp. *brittonii*	moss-pink, creeping phlox	PE	HP	
Theophrastaceae				
Samolus parviflorus [= *S. valerandi* ssp. *parviflorus*]	water pimpernel	PE	HP	
Primulaceae				
Dodecatheon meadia	shooting-star, pride-of-Ohio	PE	HP	
Myrsinaceae				
Lysimachia hybrida	lance-leaved loosestrife	PT	HP	
Lysimachia quadriflora	four-flowered loosestrife	PX	HP	
Ericaceae				
Arctostaphylos uva-ursi ssp. *coactilis*	bearberry	PX	SE	
Lyonia mariana	staggerbush	PE	SD	
Rhododendron calendulaceum	flame azalea	PX	SD	
Boraginaceae				
Cynoglossum boreale [= *C. virginianum* var. *boreale*]	northern hound's-tongue, wild comfrey	PX	HP	
Lithospermum canescens	hoary puccoon, Indian-paint	TU	HP	
Lithospermum caroliniense	golden puccoon, hispid gromwell	PE	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Onosmodium molle var. *hispidissimum* [= *O. bejariense* var. *hispidissimum*]	false gromwell, marble-seed	PE	HP	
Rubiaceae				
Galium latifolium	purple bedstraw	TU	HP	
Houstonia purpurea var. *purpurea*	purple bluets, southern bluets	TU	HP	
Houstonia serpyllifolia	creeping bluets, thyme-leaved bluets	PE	HP	
Gentianaceae				
Gentiana catesbaei	coastal plain gentian, Catesby's gentian	PX	HP	
Gentiana saponaria	soapwort gentian	PE	HP	
Gentiana villosa	striped gentian	PE	HP	
Gentianopsis virgata	narrow-leaved fringed gentian	PX	HA / HB	
Swertia caroliniensis [= *Frasera caroliniensis*]	American columbo, green gentian	PE	HP	
Apocynaceae				
Asclepias variegata	white milkweed	PE	HP	
Plantaginaceae				
Gratiola aurea	goldenpert, hedge hyssop	PE	HP	
Penstemon laevigatus	eastern beard-tongue	TU	HP	
Orobanchaceae				
Agalinis auriculata	eared false-foxglove	PE	HA	
Agalinis decemloba [= *A. obtusifolia*]	Blue Ridge false-foxglove	PX	HA	
Agalinis paupercula	small-flowered false-foxglove	PE	HA	
Castilleja coccinea	Indian paintbrush	PT	HA	
Pedicularis lanceolata	swamp lousewort, wood-betony	PE	HP	
Lamiaceae				
Monarda punctata	spotted bee-balm	PE	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Pycnanthemum verticillatum var. *pilosum*	whorled mountain-mint	PX	HP	
Scutellaria saxatilis	rock skullcap	PE	HP	
Stachys hyssopifolia var. *ambigua* [= *S. aspera*]	hedge-nettle	PX	HP	
Stachys hyssopifolia var. *hyssopifolia*	hedge-nettle, woundwort	PX	HP	
Acanthaceae				
Ruellia humilis	fringed-leaved petunia	PE	HP	
Ruellia strepens	limestone petunia	PT	HP	
Apiaceae				
Eryngium aquaticum	marsh eryngo, rattlesnake-master	PX	HP	
Ligusticum canadense	lovage, Canadian licorice-root	PE	HP	
Oxypolis rigidior	cowbane, water-dropwort	PT	HP	
Taenidia montana	mountain pimpernel	PE	HP	
Campanulaceae				
Lobelia kalmii	brook lobelia	PE	HP	
Lobelia nuttallii	Nuttall's lobelia	PX	HP	
Lobelia puberula	downy lobelia	PE	HP	
Asteraceae				
Ageratina aromatica	small-leaved white-snakeroot	PR	HP	
Antennaria virginica	shale-barren pussytoe, Virginia pussytoe	PR	HP	
Arnica acaulis	leopard's-bane	PE	HP	
Artemisia campestris ssp. *caudata*	beach wormwood	PE	HB	
Baccharis halimifolia	groundsel-tree	PR	SD	
Bidens laevis	showy bur-marigold	TU	HA / HP	
Boltonia asteroides	aster-like boltonia	PE	HP	
Chrysopsis mariana	golden aster	PE	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Cirsium horridulum	yellow thistle, horrible thistle	PE	HB	
Conoclinium coelestinum	mistflower, wild ageratum	TU	HP	
Coreopsis rosea	pink tickseed	PX	HP	
Echinacea laevigata	Appalachian coneflower, smooth purple coneflower	PX	HP	
Elephantopus carolinianus	elephant's foot	PE	HP	
Eupatorium album	white-bracted eupatorium	PX	HP	
Eupatorium godfreyanum	Godfrey's thoroughwort	TU	HP	
Eupatorium rotundifolium var. *ovatum*	round-leaved eupatorium	TU	HP	
Eupatorium rotundifolium var. *rotundifolium*	round-leaved eupatorium	TU	HP	
Euthamia caroliniana	grass-leaved goldenrod, coastal plain flat-topped goldenrod	PT	HP	
Helianthus hirsutus	hairy sunflower	TU	HP	
Helianthus microcephalus	small wood sunflower	TU	HP	
Hieracium traillii [= *H. greenii*]	Green's hawkweed, Maryland hawkweed	PE	HP	
Hieracium umbellatum [= *H. kalmii*]	Canada hawkweed	TU	HP	
Lactuca hirsuta	downy lettuce	TU	HA / HB	
Liatris scariosa	northern blazing-star	PT	HP	
Packera anonyma	Appalachian groundsel, plain ragwort	PR	HP	
Packera antennariifolia	shale-barren ragwort, cat's-paw ragwort	PE	HP	
Packera plattensis	prairie ragwort	PX	HB	
Parthenium integrifolium	American fever-few	PX	HP	
Pluchea odorata var. *succulenta*	marsh fleabane	PE	HA	
Prenanthes serpentaria	lion's-foot	TU	HP	
Ratibida pinnata	prairie coneflower	PX	HP	
Rudbeckia fulgida var. *fulgida*	eastern coneflower	TU	HP	

family / scientific name	common name(s)	state status	growth form	C_3 or C_4 (grasses)
Sericocarpus linifolius	narrow-leaved white-topped aster	PE	HP	
Solidago arguta var. *harrisii*	Harris's goldenrod	PE	HP	
Solidago rigida [= *Oligoneuron rigidum*]	stiff goldenrod	PE	HP	
Solidago roanensis	mountain goldenrod	PR	HP	
Solidago simplex ssp. *randii* var. *racemosa*	sticky goldenrod	PE	HP	
Solidago speciosa	showy goldenrod	PT	HP	
Solidago uliginosa	bog goldenrod	TU	HP	
Symphyotrichum depauperatum	serpentine aster	PT	HP	
Symphyotrichum dumosum	bushy aster	TU	HP	
Symphyotrichum novi-belgii var. *novi-belgii*	New York aster	PT	HP	
Symphyotrichum praealtum	veiny-lined aster	TU	HP	
Vernonia glauca	Appalachian ironweed, tawny ironweed	PE	HP	

Appendix E. **Rare butterfly and moth species native to grasslands, meadows, and savannas in Pennsylvania**

Species tracked by the Pennsylvania Natural Heritage Program ($N = 86$, plus 9 additional species proposed for tracking, marked by an asterisk). Where state rank is not given, data are currently insufficient to assign a rank (see Appendix F for explanation of ranking codes). The list is not exhaustive; the larval host plants for another 49 of the state's rare moth species and one rare butterfly species are unknown and many of them have been captured in grasslands, meadows, and savannas in the state.

family / scientific name	common name	global rank	state rank	larval host plant(s) native to Pennsylvania
BUTTERFLIES				
Hesperiidae				
Amblyscirtes vialis	common roadside-skipper	G5	S2S4	*Agrostis, Poa, Chasmanthium*
Atrytone arogos arogos	arogos skipper	G3T1T2	SX	*Schizachyrium scoparius*
Atrytonopsis hianna	dusted skipper	G4G5	S2S3	*Schizachyrium scoparius, Andropogon gerardii*
Carterocephalus palaemon mandan	arctic skipper	G5T5	S2	Poaceae, including *Calamagrostis, Bromus*
Erynnis martialis	mottled duskywing	G3G4	SH	*Ceanothus americanus*
Erynnis persius persius	Persius duskywing	G5T1T3	S1S2	*Baptisia tinctoria, Lupinus perennis*
Euphyes bimacula	two-spotted skipper	G4	S2S3	*Carex,* especially *C. trichocarpa, C. stricta*
Euphyes conspicuus	black dash	G4	S3	*Carex,* especially *C. stricta*
Euphyes dion	dion skipper	G4	S1	*Carex, Cladium, Scirpus*
Hesperia leonardus	Leonard's skipper	G4	S3S4	*Schizachyrium scoparius, Bouteloua, Agrostis*
Hesperia metea	cobweb skipper	G4G5	S2S3	*Schizachyrium scoparius, Andropogon*
Hesperia sassacus	Indian skipper	G5	S3S4	*Schizachyrium scoparius, Panicum, Dichanthelium*(?), *Festuca*(?)
Nastra lherminier	swarthy skipper	G5	S2S3	*Schizachyrium scoparium*

family / scientific name	common name	global rank	state rank	larval host plant(s) native to Pennsylvania
Poanes massasoit	mulberry wing	G4	S3	*Carex,* including *C. stricta*
Polites mystic	long dash	G5	S3	*Poa*
Pyrgus wyandot	Appalachian grizzled skipper	G1G2Q	S1	*Potentilla canadensis*
Thorybes bathyllus	southern cloudywing	G5	S3S4	Fabaceae, including *Desmodium, Lespedeza, Trifolium, Astragalus, Strophostyles*
Lycaenidae				
Callophrys augustinus	brown elfin	G5	S3S4	Ericaceae
Callophrys gryneus	juniper hairstreak	G5	S2S4	*Juniperus virginiana*
Callophrys irus	frosted elfin	G3	S1S2	*Baptisia tinctoria, Lupinus perennis*
Callophrys niphon	eastern pine elfin	G5	S3	*Pinus, Juniperus virginiana, Larix laricina*
Callophrys polios	hoary elfin	G5	S1	*Arctostaphylos uva-ursi*
Celastrina ladon lucia	northern spring azure	G5	S3S4	*Prunus, Vaccinium, Viburnum, Cornus, Ceanothus americana, Collinsia*
Glaucopsyche lygdamus lygdamus	silvery blue	G5T4	S1S2	Fabaceae, including *Astragalus, Lupinus, Lathyrus, Vicia*
Lycaeides melissa samuelis	karner blue	G5T2	SX	*Lupinus perennis*
Lycaena epixanthe	bog copper	G4G5	S2	*Vaccinium*
Lycaena hyllus	bronze copper	G5	SU	Polygonaceae
Parrhasius m-album	white M hairstreak	G5	S3S4	*Quercus*
Satyrium edwardsii	Edwards' hairstreak	G4	S3S4	*Quercus ilicifolia*
Nymphalidae				
Boloria selene myrina	silver bordered fritillary	G5T5	S1S3	*Viola*
Chlosyne gorgone	Gorgone checkerspot	G5	—	Asteraceae, including *Helianthus; Lysimachia*
Chlosyne harrisii	Harris' checkerspot	G4	S3	*Doellingeria umbellata*

family / scientific name	common name	global rank	state rank	larval host plant(s) native to Pennsylvania
Chlosyne nycteis	silvery checkerspot	G5	S3S4	Asteraceae, including *Rudbeckia, Helianthus, Verbesina*
Enodia anthedon	northern pearly-eye	G5	S3S4	Poaceae, including *Leersia, Brachyelytrum, Elymus, Chasmanthium*
Euphydryas phaeton	Baltimore checkerspot	G4	S2S4	*Chelone, Penstemon, Plantago, Aureolaria*
Phyciodes batesii batesii	tawny crescent	G4TH	SX	*Symphyotrichum undulatum*
Phyciodes cocyta	northern crescent	G5	S3S4	Asteraceae, especially *Symphyotrichum*(?)
Polygonia faunus	green comma	G5	SH	*Salix humilis, Betula lenta, Alnus, Ribes*
Satyrodes eurydice	eyed brown	G4	S1S3	*Carex*
Speyeria aphrodite	Aphrodite fritillary	G5	S3S4	*Viola*
Speyeria atlantis	Atlantis fritillary	G5	SU	*Viola*
Speyeria diana	diana fritillary	G3G4	—	*Viola*
Speyeria idalia idalia	eastern regal fritillary	G1	S1	*Viola*
Papilionidae				
Papilio cresphontes	giant swallowtail	G5	S2	*Zanthoxylum americanum, Ptelea trifoliata*
Pieridae				
Anthocharis midea	falcate orangetip	G4G5	S3	Brassicaceae, including *Arabis*
Colias interior	pink-edged sulphur	G5	SH	*Vaccinium*
Euchloe olympia	Olympia marble	G4G5	S1	*Arabis*
Pontia protodice	checkered white	G4	SH	Brassicaceae, Cleomaceae
Riodinidae				
Calephelis borealis	northern metalmark	G3G4	S1S2	*Packera obovata, Erigeron philadelphicus*

family / scientific name	common name	global rank	state rank	larval host plant(s) native to Pennsylvania
MOTHS				
Geometridae				
Apodrepanulatrix liberaria	a geometer moth	G4	S3	*Ceanothus*
Erastria coloraria	broad-lined erastria moth	G4	S1	*Ceanothus americanus*
Glena cognataria	blueberry gray	G4	S1	*Vaccinium, Prunus, others*(?)
Hypagyrtis esther	Esther moth	G5	S2S3	*Pinus*
Itame sp. 1 nr. *inextricata*	barrens itame	G3G4	S1	*Quercus ilicifolia*
Megalopygidae				
Lagoa crispata	black-waved flannel moth	G5	S1	generalist, including *Quercus, Sassafras*
Cicinnus melsheimeri	Melsheimer's sack bearer	G4	S1	*Quercus ilicifolia*
Noctuidae				
Acronicta albarufa	barrens dagger moth	G3G4	SX	*Quercus,* especially *Q. ilicifolia*
Apharetra purpurea	a noctuid moth	G4	S2	*Vaccinium*(?)
*Catocala dulciola**	sweet underwing	G3	SH	*Crataegus*
*Catocala gracilis**		G5	—	*Vaccinium, Lyonia*
*Catocala praeclara**	praeclara underwing	G5	—	*Prunus,* including *P. virginiana, Photinia*
Catocala pretiosa pretiosa	precious underwing moth	G4T2T3	SX	*Photinia*
Catocala sp. 1 nr. *jair*	pine woods underwing	G5	S1	*Quercus ilicifolia, other Quercus*(?)
*Cerastis fishii**		G4G5	—	*Vaccinium*
Cerma cora	bird dropping moth	G3G4	—	*Prunus pensylvanica*
Chytonix sensilis	marvel moth	G4	S1	fungi(?) following fire
*Cucullia speyeri**	a noctuid moth	G4	S4	Asteraceae, including *Conyza canadensis*
Diarsia rubifera		G5	SU	*Vaccinium*(?)
Epiglaea apiata	pointed sallow	G5	S3S4	*Vaccinium*
*Eueretagrotis attenta**	attentive dart	G4	—	*Vaccinium*

family / scientific name	common name	global rank	state rank	larval host plant(s) native to Pennsylvania
Fagitana littera	marsh fern moth	G4	SH	*Thelypteris palustris*
Hydraecia immanis	a noctuid moth	G4	SU	Poaceae
Lithomoia solidaginis germana	a moth	G5T5	S3S4	*Vaccinium*
Lithophane thaxteri	Thaxter's pinion moth	G4	SH	*Comptonia peregrina,* Ericaceae(?)
Merolonche dolli	Doll's merolonche	G3G4	S1	*Vaccinium*
*Papaipema pterisii**		G5	—	*Pteridium aquilinum*
Papaipema sp. 1	flypoison borer moth	G2G3	S2	*Amianthium muscaetoxicum*
Phoberia orthosioides	an oak moth	G4	S3	*Quercus,* including *Q. ilicifolia*
Psectraglaea carnosa	pink sallow	G3	S1	*Vaccinium*(?), *Quercus ilicifolia*(?)
Sideridis maryx		G4	S1S3	*Vaccinium*(?)
*Syngrapha epigaea**	a noctuid moth	G5	S1	*Vaccinium, Kalmia angustifolia*
Xestia elimata	southern variable dart moth	G5	S2S3	*Pinus*(?)
Xylotype capax	broad sallow moth	G4	S3	*Vaccinium*(?), *Quercus ilicifolia*(?)
Zale curema	a zale moth	G3G4	S1	*Pinus rigida*
Zale sp. 1 nr. *lunifera*	pine barrens zale	G3G4	S1	*Quercus ilicifolia*
Zale squamularis		G4	S2S3	*Pinus rigida*
Zale submediana	a zale moth			*Pinus rigida*
Notodontidae				
Datana ranaeceps	a hand-maid moth	G3G4	S1	*Lyonia, Leucothoe*
Saturniidae				
Anisota stigma	spiny oakworm moth	G5	S1S2	*Quercus,* especially *Q. ilicifolia, Q. prinoides*
Citheronia sepulcralis	pine devil	G4	S2S4	*Pinus*
Hemileuca maia	barrens buckmoth	G5	S1S2	*Quercus ilicifolia, Q. prinoides,* rarely *Q. velutina*

family / scientific name	common name	global rank	state rank	larval host plant(s) native to Pennsylvania
Sphingidae				
Hemaris gracilis	slender clearwing	G3G4	SH	Ericaceae, including *Vaccinium*
*Paonias astylus**	huckleberry sphinx	G4G5	—	*Vaccinium, Gaylussacia*
Sphinx gordius		G4	S1S3	Ericaceae(?), Myricaceae(?)

Appendix F. **Explanation of global and state rank codes**

Ranks describe rarity both throughout a species' range (globally, or "G" rank) and within Pennsylvania (statewide, or "S" rank). The rarity of subspecies and varieties is indicated with a taxon ("T") rank. For example, a G5T1 rank shows that the species is globally secure (G5) but the subspecies is critically imperiled (T1).

code	examples	description
1	G1 S1	Critically imperiled because extreme rarity (generally one to five occurrences), steep decline, or some factor of its biology makes it particularly vulnerable to extinction or extirpation.
2	G2 S2	Imperiled because rarity (generally six to 20 occurrences), steep decline, or other factors demonstrably make it very vulnerable to extinction or extirpation.
3	G3 S3	Either very rare and local throughout its range (generally 21 to 100 occurrences), or found locally (even abundantly at some of its locations) in a restricted range, or vulnerable to extinction because of other factors.
4	G4 S4	Widespread and apparently secure, although the species may be quite rare in parts of its range, especially at the periphery.
5	G5 S5	Demonstrably widespread and secure, although the species may be quite rare in parts of its range, particularly at the periphery.
U	GU SU	Status uncertain, but possibly in peril. More information needed.
H	GH SH	Known only from historical records, but may be rediscovered. A G5 SH species is widespread throughout its range (G5), but considered historical in Pennsylvania (SH).
X	GX SX	Believed to be extinct. May be rediscovered, but evidence indicates that this is less likely than for historical species. A G5 SX species is widespread throughout its range (G5), but extirpated from Pennsylvania (SX).
E	SE	An exotic that is established in the state, but may be native in nearby regions.

The following modifiers indicate that there is some question about a species' rank.

code	examples	description
Q	G5Q GHQ	Questions or problems may exist with the species' or subspecies' taxonomy, so more information is needed.
?	G3? S3?	The rank is uncertain due to insufficient information at the state or global level, so more inventories are needed. When no rank has been proposed the rank may be "G5T?" or "S?"

The following modifiers indicate when the breeding status of a migratory species is considered separately from individuals passing through or not breeding within Pennsylvania. These modifiers are only attached to state ranks.

code	examples	description
B	SHB	Indicates the breeding status in Pennsylvania of a migratory species.
N	S1N	Indicates the non-breeding status in Pennsylvania of a migratory species. These species are typically over-wintering birds with regular aggregation areas that could be conservation targets.
Z	SZN	Indicates that non-breeding occurrences of a species are not tracked by the Pennsylvania Natural Heritage Program. These species are typically birds that over-winter sporadically in Pennsylvania.

Breeding-status modifiers may be used alone or in combinations. For example:

S3B,SZN	Breeding occurrences are uncommon (S3B), and over-wintering birds are not tracked (SZN).
SHB,SZN	Only historical records of breeding are known (SHB), and over-wintering birds are not tracked (SZN).
S3B	Breeding occurrences are uncommon (S3B), and the species does not over-winter in Pennsylvania.
SUB,S1N	The breeding status of the species is unknown (SUB), and any wintering site is critically imperiled or extremely rare (S1N) regardless of breeding status.

When ranks are somewhat uncertain or the species' status appears to fall between two ranks, the ranks may be combined. For example:

G4G5	The species may be globally secure (G5), but appears to be at some risk (G4).
G5T2T3	The species is globally secure (G5), but the subspecies is somewhat imperiled (T2T3).
G4?Q	The species appears to be relatively secure (G4), but more information is needed to confirm this (?). Further, there are questions or problems with the species' taxonomy (Q).
G3G4Q S1S2	The species is globally uncommon (G3G4), and there are questions about its taxonomy (Q). In Pennsylvania, the species is very imperiled (S1S2).