Pink Hill

Serpentine Barrens Restoration and Management Plan

For the

John J. Tyler Arboretum
Media, Pennsylvania

In cooperation with the

Mt. Cuba Center
Greenville, Delaware

By

Roger Latham

www.continentalconservation.us
Rose Valley, Pennsylvania

Cover photo: Moss phlox (*Phlox subulata* L. ssp. *subulata*), sometimes called “mountain pink,” is the source of Pink Hill’s name and much of its fame.

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Introduction

The Pink Hill serpentine barrens is an extraordinary ecosystem with a history extending back into the deep past. It is home to an extraordinarily diverse group of plants and animals for such a small area of land, including several rare, threatened and endangered species. There is strong evidence that the barrens lost considerable ground in the latter half of the twentieth century, shrinking in area and declining in native species diversity with the waning of the disturbance regime that sustained it for centuries or thousands of years. In the past few years, considerable progress has been made to begin the process of ecological restoration, but much still needs to be done before Pink Hill will recoup its losses. With strategically targeted effort, this significant piece of the region's natural heritage can be brought back to top condition and its key processes restored to insure its long-term sustainability.

Background on serpentine barrens

The open grasslands, greenbrier thickets and scattered, stunted trees at Pink Hill are collectively called serpentine barrens: *barrens* because farmers long ago discovered that the soils were poor for growing crops, and *serpentine* because the main cause of the infertility—the bedrock from which the soils are weathered—is a rare rock formation called serpentinite. Serpentine grassland is one of the rarest natural communities in eastern North America. Grassland and the other plant communities that make up serpentine barrens live on thin soils overtop a geologic oddity, a metamorphic, greenish rock formed in deep cracks on the seafloor. Most of the earth's supply of serpentinite still lies buried under the seafloor, far beneath the surface of the world's oceans. It is rare on the continents, present in North America, for example, only in a few scattered, isolated patches from Georgia to Newfoundland and in Alaska, Oregon, California, Costa Rica and Cuba.

The serpentinite underlying Pink Hill and some of the adjoining forestland formed beneath a predecessor to the Atlantic Ocean a half-billion years ago. During an extremely slow but almost inconceivably colossal collision of North America with Africa that swept up a volcanic island arc similar to today's Japanese archipelago, this ocean was squeezed out of existence. Most of the sea-bottom rock was overridden by the drifting continents and pressed downward into the earth's molten interior, but a few broken pieces caught on the continent's edge and stuck there. Like cars crashing in slow motion, the two continents' crumpled leading edges compressed horizontally and rose vertically, forming a Himalaya-sized mountain range, much as the Himalayas are still forming today while India, once a huge island, continues its ongoing slow collision with the rest of Asia. The few fragments of ocean-bottom rock that had jumbled together with the continental rocks at the suture line, including the Pink Hill serpentinite, lay deep inside the mountains. North America and Africa parted once again and a hundred million years of erosion by rain and landslides slowly wore the mountains down, depositing most of their bulk as silt and rubble on the continental shelf off the Atlantic coastline and in a shallow sea that covered the Ohio and Mississippi valleys. The igneous and metamorphic rocks of the present-day Piedmont, including small, scattered areas of serpentinite, were deep inside the core of that long-gone mountain range.

The soil that forms overtop serpentinite bedrock is different from any other soil in the world. It has unusually high levels of

magnesium, nickel and chromium and very low calcium content. Because the plant life of serpentine barrens is stunted, the soil is often assumed to be overly well drained and sandy like the coastal plain soils of the New Jersey Pine Barrens. This is a misconception. Serpentine soil is actually a moist loam, with texture and moisture content comparable to a good agricultural soil[1]. It is the soil's peculiar chemical characteristics that make it a challenging medium for plant growth. Most plants need much more calcium than serpentine soil can provide. At the same time magnesium, an essential mineral for plant growth, is present in such high concentrations that it can be toxic, a textbook case of "too much of a good thing." In parts of some serpentine barrens, the heavy metals nickel or chromium also are abundant enough to deter the growth of many plant species.

The thinner the soil over serpentinite bedrock, the more pronounced the effects are of low calcium and high magnesium, nickel and chromium. Where the soil is thinnest at Pink Hill, the plants that grow best are prairie grasses such as little bluestem, Indian-grass, arrow-feather three-awn and poverty three-awn. A variety of other grasses, sedges, rushes and wildflowers also inhabit the thinnest soil, including all of Pink Hill's rare, threatened or endangered species (plant species known to live at Pink Hill are listed in the Appendix). The grassland at Pink Hill is sometimes called a serpentine savanna (see box below) because stunted trees, mainly blackjack oak, Virginia pine and eastern red-cedar, grow sparsely there.

Relatively few species of plants are equipped to deal with the unusual chemistry of serpentine soil. Even the characteristic plants of serpentine barrens have stunted growth on serpentine soil, but unlike ordinary plants, they can "tough it out." Still, they pay a price for this ability. The anatomical and biochemical inner workings that enable some plants to tolerate extreme soil conditions are so costly in energy and resources that such plants are incapable of the rapid growth needed to compete successfully with common plants on ordinary soil. They grow faster and larger on more fertile soil, but not as fast or as large as ordinary plants that lack the ability to endure on serpentine soil. This is the key to why the serpentine barrens flora is very different from any other plant community in the region. The characteristic plants of the serpentine barrens are poor competitors in forests and other commonplace habitats surrounding the barrens. Likewise, the plants that are good competitors on ordinary soil lack the ability to thrive on serpentine soil.

WHAT IS THE DIFFERENCE BETWEEN A GRASSLAND AND A MEADOW?

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

[1] Hull and Wood 1984; Latham 1993

Even though the serpentine barrens plants are adapted to the harsh conditions, the soil chemistry by itself is not enough to sustain them in the long term. They depend on periodic disturbance to prevent replacement by forests. For millions of years (with interruptions during the past two million years by more than a dozen ice ages), such disturbance for the most part probably resulted from foraging, trampling, bedding down and wallowing by large, plant-eating animals. In what is now Pennsylvania and the mid-Atlantic region, woolly mammoth, Columbian mammoth, American mastodon, Wheatley's ground sloth and Jefferson's ground sloth[1] shaped ecosystems by killing trees, scarifying and compacting the soil, and starting a cascade of indirect effects[2], resulting in a patchwork of persistent grasslands within a matrix of forest. Herds of mid-sized herbivores would have kept some of the areas disturbed by the giant herbivores open and in grass cover, just as they do in Africa today where the presence of elephants is associated with the persistence of grasslands, even where there is enough rain to support forests[3]. In east-central North America those mid-sized grazers and browsers were eastern elk, moose, white-tailed deer, American bison and a host of now-extinct species, among them the black bear-sized giant beaver, giant horse, complex-toothed horse, Cope's tapir, vero tapir, long-nosed peccary, Leidy's peccary, flat-headed peccary, fugitive deer and stag-moose[1]. The extinctions of the last native elephants and giant ground sloths and most of the mid-sized "megafauna" occurred nearly simultaneously with a wave of human immigration or cultural change around 13,000 years ago. Ironically, when people began opening up grasslands in eastern North America thousands of years ago by setting fires, they restored some of the habitat diversity that had declined when nearly all of the megaherbivores died out, a catastrophe that most likely had been caused, directly or indirectly, by them or their ancestors.

The dependence of grasslands in our part of the world on disturbance—first by megaherbivores, later by fire, and still later by livestock grazing and mining—involves the process ecologists call *succession*. Succession refers to the gradual replacement of one kind of ecological community by another on the same piece of land. The most familiar example of succession in our part of the world is what happens when a farm field is abandoned. There is a constant rain everywhere of seeds of many plant species, including trees. Abandoned cropland or pasture usually has a residue of nutrients added in fertilizer or manure, which fosters the rapid establishment and growth of seedlings. In early succession, plants of different growth forms, whether they are trees, shrubs, grasses or herbs, are all small in stature. In mid-succession, trees and shrubs have grown taller than their herbaceous neighbors. Still later, the trees outstrip the shrubs in height and the plant community becomes a young woodland or forest. When some of the trees have reached full maturity, a forest has entered late succession. Any often-observed sequence of this type is called a successional pathway.

The unusual soil chemistry in serpentine grassland together with crowding by the dense grasses make it hard for most of the tree species native to our region to germinate and survive. However, in the absence of disturbance, a transformation occurs along the margins of the grassland patches where grass meets forest. Each year, full-grown forest trees in our region deposit 10 to 20 tons or more of dead leaves per acre[4]. These leaves decompose and enrich the soil, forming a thick layer of humus. The humus layer is so rich in nutrients and available moisture that forest plant species concentrate most of their root growth there. This rich, uppermost soil

[1] Guilday 1971; Kurtén. and Anderson 1980; Williams at al. 1985; Dr. Russell Graham, personal communication (2007)

[2] Milchunas et al. 1988; Folke et al. 2005; Zimov et al. 1995

[3] Dublin et al. 1990

[4] José-Luis Machado, personal communication (2005)

layer also forms beneath the overhanging trees along the grassland edge, making the soil there suitable for colonization by trees, shrubs and invasive plants, even those species that are sensitive to the unusual chemistry of serpentine soil[1]. Furthermore, the partial shade at the forest edge suppresses the native grassland plants, which are intolerant of shade, while favoring the growth of tree seedlings and other forest species, which are intolerant of the extreme heat in the middle of a patch of grassland. Disturbances that kill adult trees, remove tree seedlings, or consume or remove dead leaves and other organic matter inhibit soil buildup. Only with regular disturbance do grasslands such as those at Pink Hill persist in spite of succession.

Pink Hill's exceptional diversity of grassland-specialist plants and the large number of rare species are good indicators that grassland has existed there for a very long time. We have no direct evidence farther back than the earliest botanical records in the 1800s, but high grassland diversity and the cluster of rare species are solid clues that the grassland's age may be on the order of at least a thousand years. Its origin might date back to the most recent major episode of global warming, which occurred between 8,000 and 4,500 years ago. With warming came frequent drought, and with each drought, a setback for succession—young trees dying for lack of water—and more widespread and frequent wildfires. But the climate turned cooler and wetter around 4,500 years ago and stayed that way until at least the mid-twentieth century, reducing the incidence of lightning-ignited wildfires to what it has been during recorded history in the region, which is near zero. Some Native American cultural groups regularly burned their woods and fields and many ecologists accept that it was this practice that made it possible for the barrens to persist until European settlement. Indians who used fire to modify the landscape in eastern North America did it most likely to improve game habitat, encourage the growth of certain fire-enhanced sources of food such as blueberries, huckleberries, blackberries and raspberries, and extend visibility, which would have made it easier to hunt, travel and maintain "homeland security."

There is no direct evidence—no "smoking flint"—of Native American burning at Pink Hill, but several lines of circumstantial evidence point to a strong likelihood that the grassland is, in essence, an Indian artifact. Despite what most of us were taught in history class, not all of the mid-Atlantic region was forested when the Europeans first arrived. Evidence is still accumulating from pollen core analysis and other scientific means to confirm what is implied in the earliest historical writings, namely, that grasslands and meadows were far more widespread in prehistoric eastern North America than has been generally appreciated. After Native Americans were largely displaced from the East, nearly all of the grasslands and meadows succeeded into forests or were converted into plowed farm fields. Only where the soils were too poor to grow crops or to support rapid invasion by forest trees (for instance, the thin soil over serpentinite bedrock) were native grasslands sustained after the Indians' departure. Even many of these places were covered over by forest vegetation eventually. Only the few acres that were kept cleared by livestock grazing, accidental wildfires, intentional burning, or mining still have native grassland vegetation today. The grasslands that persisted the longest were those where plant growth is slowest due to unfavorable soil or microclimate, because there it took fewer and less frequent disturbances to keep the normal process of forest establishment at bay.

Native grasslands in the northeastern United States stir esthetic as well as scientific interest because they are rare and beautiful landscapes and because they are habitats for unusual clusters of rare species. But part of the value and appeal of the serpentine barrens, in particular, also is cultural, historic and anthropological. Despite their wild appearance they are relics of an ancient way of life, a part

[1] Barton and Wallenstein 1997

of our cultural heritage. Any formerly Indian-maintained grasslands that still persist in the northeastern United States have been preserved and maintained, however inadvertently, by Westerners ever since they replaced Native Americans as stewards of the land. It is only recently that conservation agencies and private groups like the Tyler Arboretum have made the long-term stewardship of such places intentional.

The importance of grassland conservation

Scientists conducting a global study of conservation needs recently tallied the total areas of habitat converted or destroyed and of habitat protected in all of the major ecosystem categories worldwide[1]. The picture is upbeat for certain ecosystems—including tundra, boreal forest and taiga, montane grassland and shrubland, and temperate conifer forest—but it is bleak for many others. Of all ecosystem types evaluated, temperate grassland, the category that includes the open area at Pink Hill, is in the direst straits. For temperate grassland (including savanna) and shrubland together, the ratio of acres destroyed to acres protected is ten to one, five times higher than even the beleaguered tropical rainforest. Worldwide, only 5% of the land in temperate grassland and shrubland has been protected to date while 46% has already been destroyed. The figures are even more dismal for the eastern United States, where native grasslands have been under extreme pressure for more than 300 years and most were converted long ago to agricultural, residential, commercial and other uses.

Historically, meadows and grasslands occurred as breaks in the eastern deciduous forest resulting from disturbances such as fire, periodic flooding, insect infestation and clearing by humans—first by American Indians and later by settlers from the Old World. Most meadows and grasslands in eastern North America are short-lived ecosystems. Without repeated disturbance, trees and other forest plants seed in rapidly and reestablish the forest.

Since the first European settlement, native meadows and grasslands have steadily declined. These plant communities were once composed of hundreds of native plant species that, for millions of years, provided the highest quality food and habitat for native meadow wildlife. The typical meadow today is an abandoned field invaded by a few introduced species—multiflora rose, autumn-olive, Japanese honeysuckle, Amur honeysuckle, Canada thistle, mile-a-minute and Japanese stilt-grass are examples—that crowd out the native plants and degrade the habitat for most native animal species. Native grasslands and meadows are now rare indeed.

Simply protecting native grasslands and meadows in rainy eastern North America is not enough to sustain them. Where it is left unimpeded the process of forest soil-building transforms the unique native grassland community, with its high species diversity and many rare species, to common forests of moderate to very low species diversity and abundant introduced invasive species. Examples of introduced invasive plants that are common in the woods near the edges of the Pink Hill grasslands are ailanthus, Oriental bittersweet, Japanese honeysuckle, Amur honeysuckle, multiflora rose and Japanese stiltgrass. Even some native species can take advantage of the soil-building and heat-shielding opportunities of the forest-grassland edge and begin overrunning the grassland, including red maple and greenbrier. One species that was introduced from farther west in North America, black locust, invades the grassland in a different way—established trees in the surrounding woods send in underground runners, new stems shoot up from those runners in what would ordinarily be hostile territory, and the "mother" trees subsidize shoots' water and nutrient needs through the runners until they build up enough soil organic matter beneath themselves from shed,

[1] Hoekstra *et al.* 2004

nitrogen-rich leaves to support healthy root systems of their own. The result of invasion by forest plants and nonnative plants is the shrinkage and disappearance of the grassland ecosystem and all of its characteristic species. The eventual result would be the tragic and irreversible loss of an extraordinary ecosystem that has existed for thousands of years.

Most meadows in southeastern Pennsylvania have a recent agricultural past—old hayfields or pasture—and are dominated by nonnative cool-season grasses (see box at right) planted for two centuries or more as fodder, such as tall fescue, perennial ryegrass, Kentucky bluegrass, orchard grass, and timothy. Grasslands and meadows of native warm-season grasses and other plants are now rare but they provide far better habitat for many species of native wildlife, especially birds, than do old fields dominated by nonnative plants, which have become much more common. Native grasses, both warm-season and cool-season, are mainly bunchgrasses, unlike the sod-forming growth habit of most nonnative hay, pasture and lawn grasses. Grasses growing in tufts with space in between provide high-quality nesting sites and allow grassland birds and other animals to move more easily and with better protection from predators in their search for food. The space between clumps also provides room for native wildflowers. More importantly, native grasslands and meadows are more valuable to wildlife than old fields with mostly nonnative plants because they are also far better habitats for insects. Insects are vital links in many of the food chains that make up the food web in ecosystems. Most insect species are specialist feeders on just one native plant species or a narrow range of species. The close associations between the insect and plant species native to our region developed over millions of years. Nonnative invasive plants seldom are utilized as a food resource by native insect species, which is one of the reasons why they are invasive. Insects are the richest source of fats and protein for birds and for many small animals that, in turn, are food for larger animals. The result is that far less of the total plant biomass is converted, via the food chains that make up the food web, into animal biomass where nonnative plants are abundant. The higher the cover and species richness of native plants in a patch of grassland or meadow, the higher the total insect biomass will be, which, in turn, enables native wildlife species to reach and sustain full abundance and diversity.

WARM-SEASON AND COOL-SEASON GRASSES

Cool-season grasses, so named because they grow best during spring and fall, have photosynthetic machinery like most other kinds of plants, a system called C_3 for short. Warm-season grasses, which grow mainly in the heat of summer, have a specialized system called C_4, which works in a manner similar to a turbocharger in a car engine, delivering carbon dioxide much more efficiently (using far less water) to the sunlight-powered parts of the plants' cells that combine CO_2 with H_2O to produce sugars, fueling growth. The C_4 system enables warm-season grasses to continue photosynthesizing and growing when most plants are forced by heat or dry soil conditions to shut down. Native grasses in southeastern Pennsylvania grasslands and meadows include more cool-season than warm-season species, but warm-season grasses are often more abundant, especially where site conditions are stressful, for instance, droughty soils or serpentine soils. Native warm-season grasses can thrive on marginal soils and survive periods of low rainfall due to their C_4 photosynthetic system and deep fibrous root systems.

Project Area

Description

Pink Hill, for the purposes of this plan, is defined as the area near Painter Road between Barren Road and Dismal Run of nearly 14 acres that was in open grassland or pasture in 1937, when the earliest aerial photograph was taken (see Figure 1). This is the maximum recorded extent of Pink Hill's serpentine grassland vegetation, although in all probability it covered a larger area in 1701, when it first appeared in the historical record in a warrant—a survey order granted by the Proprietorship of William Penn in response to an application for a land claim—on a "*Tract of Vacant Land lying between the lands of Geo. smedly, David Ogden, Thomas Minshal and Ridly Creek … left out and untaken up hitherto because of its Excessive barrenness.*"[1] The warrantee, Henry Hollingsworth, who owned a mill and six acres along Ridley Creek, requested "*a grant of the said Land for the conveniency of Firing, etc.*"[1] The tract was about ⅓ mile wide and extended from Ridley Creek west-southwestward for 1½ miles (roughly to present-day Van Leer Avenue and the Granite Run Mall). In the minutes to the meeting at which the warrant was made official, the entire 327-acre tract was called "the Barrens" but there is no doubt that the actual serpentine savanna covered just a fraction of the total. We can only speculate what was meant by "*the conveniency of Firing*" but perhaps it reflected the applicant's wish to have a ready source of firewood, which would have been plentiful in the wooded portions of the tract.

Part of this study also focuses on the historical serpentine grasslands within 2½ miles of Pink Hill. This local group—eight sites mentioned in botanical records[2] including Pink Hill—formed an archipelago of habitat "islands" in central Delaware County (see Figure 2). Species of serpentine-grassland-restricted animals and plants were distributed among these sites as *metapopulations*—groups of partially isolated populations belonging to the same species. The subpopulations of a metapopulation are interconnected by occasional cross-migration, by which gene flow among habitat islands is maintained and individuals can recolonize a site where a species has died out locally. The purpose for including all eight sites in the analysis is to identify, as thoroughly as botanical records allow, the overall species composition of the local serpentine grasslands. The grassland at Pink Hill is now the only one left, but native grassland species recorded historically at any site within the cluster could be reintroduced from seed collected at present-day remnant serpentine barrens in nearby Chester County as part of the restoration program.

Records mention six distinct areas of serpentine barrens vegetation on the plateau between Ridley Creek and Chester Creek in Middletown Township, Delaware County, collectively known to early botanists as the Middletown Barrens: Pink Hill (also described in botanical records as *near Dismal Run* or *northeast of Lima*), Glen Riddle Barrens, Lenni Barrens, Mineral Hill (*near Black Horse Hotel* or *near Elwyn*), the valley west of Black Horse Hotel (site of the present-day Granite Run Mall) and Williamson School Barrens (*Chrome Run*). The other two sites in the cluster were located between Crum Creek and Ridley Creek in Upper Providence Township, Delaware County: Bear Hill (*Worrell*) and Blue Hill. The next nearest serpentine grasslands to this cluster mentioned

[1] Pennsylvania Archives, Second Series, Volume XIX, pages 245, 271.

[2] Harshberger 1903; Pennell 1910, 1912; herbarium records in the Pennsylvania Flora Project database, Morris Arboretum of the University of Pennsylvania, courtesy of Tim Block and Ann Rhoads

in the historical record are also now gone or nearly so: two in Newtown Township, Delaware County (Fawkes Run Barrens and Preston Run Barrens), and one in Willistown Township, Chester County (Cedar Barrens). The closest serpentine grassland that is still intact is near Sugartown, Willistown Township, 7¼ miles northwest of Pink Hill. Long known as Sugartown Barrens and now a part of the Willisbrook Meadows Preserve, it is owned, managed and undergoing restoration by Natural Lands Trust. It is conceivable that individuals of serpentine-restricted plant or animal species from Sugartown Barrens might randomly turn up at Pink Hill (or vice-versa), but such exchanges are expected to occur so rarely over that distance as to be insignificant within any reasonably relevant period of time.

Biodiversity conservation significance

Delaware County used to have the second-highest number of serpentine barrens of any county in the eastern United States. But of the ten serpentine barrens sites that once existed in the county (named above), all have been lost to development or neglect except for Pink Hill. Six serpentine barrens have also been destroyed in Chester County and another in New Castle County, Delaware—the only one in that state. In Pennsylvania, eight serpentine barrens still persist in Chester County and two in Lancaster County. Elsewhere there are four serpentine barrens in Maryland, two or three small sites on Staten Island, New York, and one site each in North Carolina and Georgia. The small areas of savanna at those sites comprise the total extent of the globally rare eastern North American serpentine grassland ecosystem, which is host to more than 100 rare species, including several that are themselves globally rare. There are other plant communities atop rare outcrops of serpentinite bedrock in other parts of North America and on other continents and islands, but they are entirely different ecosystems with no plant species in common with the eastern North American serpentine grasslands.

Pink Hill boasts a healthy population of the globally rare serpentine aster.

Collectively, the eight sites of the Middletown-Upper Providence cluster were home to at least 37 plant species now officially classified as species of special concern in Pennsylvania (see Table 1). Of these, just four were recently confirmed as still living at Pink Hill, including one globally rare species endemic to eastern serpentine grasslands[1] (serpentine aster); seven others are documented as having lived at Pink Hill historically but were not found in a 2008

[1] Gustafson and Latham 2005

survey. The three-acre remnant at Pink Hill is essentially all of the potential habitat that remains, almost certainly less than $\frac{1}{10}$ and perhaps as little as $\frac{1}{30}$ of the habitat area that existed locally when all eight sites were intact.

Except for serpentine aster, the plant species of special concern at the serpentine barrens in Delaware County are—or were—at the edges of their species' main ranges, or disjunct (separated) from them. Most live mainly in the drier Midwest, or in the hotter South, or on the sandy Atlantic Coastal Plain. The ranges of a few even extend into the Southwestern deserts and parts of Mexico. Disjunct and peripheral populations are of special conservation concern in part because their members usually are genetically distinct from individuals of the same species living elsewhere. In many cases these populations are where the most rapid evolution is taking place. Any mutation that happens to increase survival or reproduction under local conditions can quickly spread throughout a small, isolated population. If they have been isolated for long enough and far enough from their species' main range, some disjunct and peripheral populations when studied intensively are found to be new varieties or subspecies or even new species. This likelihood is higher the more specialized the habitat is; grassland underlain by serpentine soils is a prime example.

Most of the rare species discussion has been about plants, but there is no doubt that animal species now classified as endangered, threatened or rare were present in the local cluster of serpentine grasslands and it is likely that a few populations still persist at Pink Hill (see examples in Table 2). Only one has been confirmed—Dr. Al Wheeler, Jr. discovered the rare mirid (plant bug) *Polymerus tinctipes*, a specialist feeder on moss phlox, in 1989–1994 at Pink Hill[1]. To date no one has done a systematic animal survey at the site. At least 47 rare butterfly and moth species inhabit Pennsylvania serpentine barrens[2]. Scientists expect to find many more kinds of rare animals as more species groups and more serpentine barrens sites are surveyed. So far, relatively little effort has been put into wildlife surveys except to search for butterflies and moths at a few sites.

Eleven rare butterfly species and 37 rare moth species are known to live in serpentine barrens in Pennsylvania (see Table 2). This represents 17% of the butterfly species and 32% of the moth species currently listed by the Pennsylvania Natural Heritage Program as candidates for endangered or threatened status—fractions vastly disproportionate to the relatively minuscule area of serpentine barrens. Most, if not all, are specialist feeders as larvae on plants that are locally abundant in serpentine grasslands, but the larval host plants of 22 of the 47 rare Lepidoptera that have been captured as adults in Pennsylvania serpentine barrens are still unknown.

The list (Table 2) is not exhaustive; other rare Lepidoptera species in the region depend on host plants that now or once lived at Pink Hill. Three moths, an unnamed geometer (*Apodrepanulatrix liberaria*), northern spring azure (*Celastrina ladon lucia*) and broad-lined erastria (*Erastria coloraria*), feed on New Jersey tea; the persius duskywing (*Erynnis persius persius*) feeds on wild indigo; arogos skipper (*Atrytone arogos arogos*), Indian skipper (*Hesperia sassacus*) and swarthy skipper (*Nastra lherminier*) feed on little bluestem and other serpentine barrens grass species; and tawny crescent (*Phyciodes batesii batesii*) feeds on clasping heart-leaved aster[3].

Nearly half of the sites that once supported the eastern serpentine grassland ecosystem, from Georgia to New York, have been destroyed. The critical habitats that they once provided for a host of rare, threatened and endangered species are permanently lost. Arguably, all of the still-intact sites that have a chance at long-term viability are globally significant, including Pink Hill.

[1] Wheeler 1995
[2] Orndorff and Patten 2007
[3] Latham and Thorne 2007; Betsy Leppo and John Rawlins, personal communication (2007)

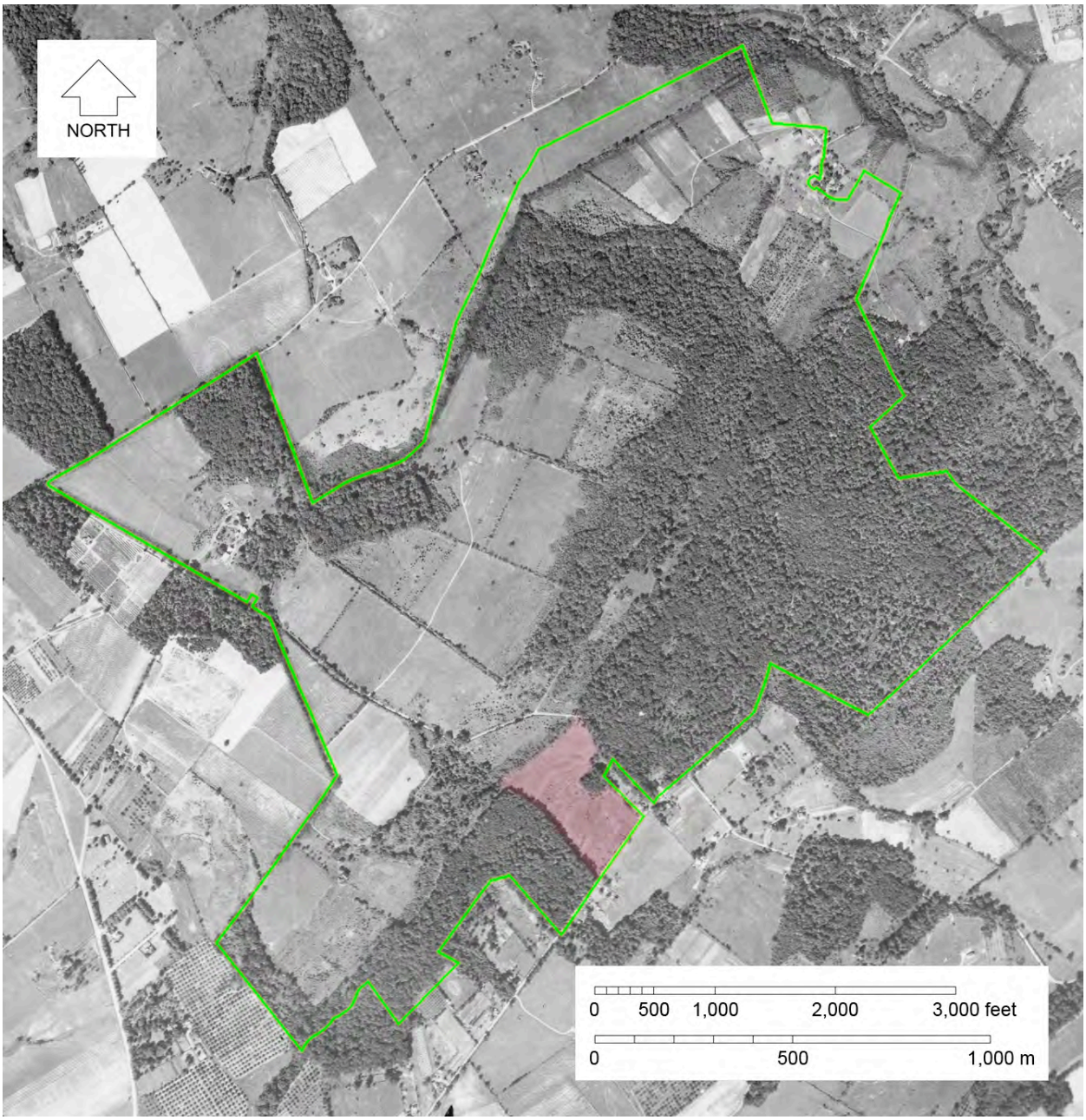


Figure 1. **Extent of Pink Hill grassland in 1937** (pink shading). The present-day borders of the Tyler Arboretum (green line) are superimposed on the earliest available aerial photograph of the area, taken on 18 September 1937. (See Figure 3 for a detailed map of the changes in grassland area from 1937 to 2005.)

Table 1. **Rare, threatened or endangered grassland plants documented historically at the eight sites of the Middletown-Upper Providence serpentine barrens cluster**[1]. State status: **PE** = endangered; **PR** = rare; **PT** = threatened; **PX** = extirpated; **TU** = status tentatively undetermined and under study. Shading indicates known status at Pink Hill: **pink** = recently confirmed as present at Pink Hill (based on field investigation by the author); **violet** = recorded historically at Pink Hill[1] (recorded place names are sometimes ambiguous and might in one or two cases refer to a neighboring site).

scientific name	common name(s)	state status	sites where recorded (of 8)
Ageratina aromatica	small-leaved white-snakeroot	PR	5
Aletris farinosa	colic-root	PE	1
Andropogon gyrans	Elliott's beardgrass	PR	1
Aristida purpurascens	arrow-feather three-awn	PT	5
Buchnera americana	bluehearts	PX	3
Carex bicknellii	Bicknell's sedge	PE	4
Castilleja coccinea	Indian paintbrush	PT	6
Cirsium horridulum	yellow thistle, horrible thistle	PE	2
Deschampsia cespitosa	tufted hairgrass	TU	2
Desmodium glabellum	tall tick-trefoil	TU	3
Desmodium nuttallii	Nuttall's tick-trefoil	TU	1
Desmodium obtusum	stiff tick-trefoil	TU	3
Dichanthelium annulum	annulus panic grass	PT	8
Dichanthelium oligosanthes	Heller's witchgrass, Scribner's panic grass	TU	7
Dichanthelium villosissimum	long-haired panic grass	TU	1
Dichanthelium yadkinense	Yadkin river panic grass	TU	1
Fimbristylis annua	annual fimbry	PT	4
Gentiana saponaria	soapwort gentian	PE	1
Gentiana villosa	striped gentian	PE	1
Helianthemum bicknellii	Bicknell's hoary rockrose	PE	3
Juncus dichotomus	forked rush	PE	1
Linum intercursum	sandplain wild flax	PE	1
Packera anonyma	Appalachian groundsel, plain ragwort	PR	4
Paspalum setaceum var. *muhlenbergii*	slender beadgrass, Muhlenberg's hairy beadgrass	TU	2
Phlox pilosa	downy phlox, prairie phlox	PE	2
Prenanthes serpentaria	lion's-foot	TU	2
Rosa virginiana	Virginia wild rose	TU	2
Scleria pauciflora	few-flowered nut-rush	PT	4

(table continued on next page)

[1] Based on herbarium records in the Pennsylvania Flora Project database, Morris Arboretum of the University of Pennsylvania (courtesy of Tim Block and Ann Rhoads) and early twentieth-century field records by the botanist Francis W. Pennell (Pennell 1910, 1912).

scientific name	common name(s)	state status	sites where recorded (of 8)
Scleria triglomerata	whip-grass, nut-rush	TU	1
Scutellaria serrata	showy skullcap	PE	1
Smallanthus uvedalia	bear's-foot, leaf-cup	PT	1
Spiranthes tuberosa	slender ladies'-tresses	PX	1
Spiranthes vernalis	spring ladies'-tresses	PE	2
Stylosanthes biflora	pencil-flower	PE	4
Symphyotrichum depauperatum	serpentine aster	PT	2
Symphyotrichum ericoides ssp. *ericoides*	white heath aster	TU	5
Vernonia glauca	Appalachian ironweed, tawny ironweed	PE	2

Table 2. **Rare butterflies and moths found in Pennsylvania serpentine barrens**[1]. Rarity ranks: **G** = throughout the species' entire range; **S** = statewide in Pennsylvania; **1** = critically imperiled because extreme rarity, steep decline, or some factor of its biology confers severe vulnerability to extinction or extirpation; **2** = imperiled because rarity, steep decline, or other factors confer high vulnerability to extinction or extirpation; **3** = very rare and local throughout the species' range or found locally in a restricted range, or vulnerable to extinction because of other factors; **4** = widespread and apparently secure; **5** = demonstrably secure (G5 ranks are omitted to make the table more readable); **H** = known only from historical records, but may be rediscovered; **U** = status uncertain, but likely in peril (more information is needed). Multiple ranks indicate uncertainty and the need for more information.

scientific name	common name	rarity: global rank	rarity: state rank	larval host plant(s), if known, occurring at or near Pink Hill
RARE BUTTERFLIES				
Amblyscirtes vialis	common roadside-skipper		S2S4	grasses
Anthocharis midea	falcate orangetip		S3	*Arabis lyrata, Cardamine*
Atrytonopsis hianna	dusted skipper		S2S3	*Schizachyrium, Andropogon*
Calephelis borealis	Northern metalmark	G3G4	S1S2	*Packera anonyma*?
Callophrys gryneus	juniper hairstreak		S2S4	*Juniperus virginiana*
Callophrys irus	frosted elfin	G3	S1S2	*Baptisia tinctoria*
Calycopis cecrops	red-banded hairstreak		S4	*Rhus* (dead leaves)
Erynnis martialis	mottled duskywing	G3G4	SH	*Ceanothus americanus*
Hesperia leonardus	Leonard's skipper		S3S4	
Hesperia metea	cobweb Skipper		S2S3	
Staphylus hayhurstii	Hayhurst's scallopwing		SU	*Chenopodium album*

(table continued on next page)

[1] Orndorff and Patten 2007: pages 43-44

scientific name	common name	rarity: global rank	rarity: state rank	larval host plant(s), if known, occurring at or near Pink Hill
RARE MOTHS				
Anisota stigma	spiny oakworm moth		S1S2	
Apodrepanulatrix liberaria	a geometer moth		S3	
Artace cribraria	dot-lined white moth		S1	*Quercus*
Caripeta aretaria	southern pine looper moth		S1	
Catocala umbrosa	an underwing moth		S1	
Cisthene packardii	Packard's lichen moth		S1S3	
Cisthene plumbea	lead colored lichen moth		S1	
Citheronia regalis	regal moth		SU	
Citheronia sepulcralis	pine devil		S2S4	
Crambidia pura	pure lichen moth		SU	
Cyclophora nanaria	a geometrid moth		S1S2	
Elaphria cornutinis	a noctuid moth		SU	
Elaphria festivoides	a noctuid moth		S5	
Erastria coloraria	broad-lined catopyrrha		S1	
Hemileuca maia	barrens buckmoth		S1S2	*Quercus marilandica*
Holomelina laeta	joyful holomelina moth		S1S2	
Hypagyrtis esther	esther moth		S2S3	
Idaea eremiata	a geometer moth		S1	
Idaea violacearia	a wave moth		S1	
Lagoa crispata	black-waved flannel moth		S1	
Macrochilo hypocritalis	an owlet moth		SU	*Carex*
Metaxaglaea semitaria	footpath sallow moth		S2	*Vaccinium*
Panthea sp. 1	a moth		SU	*Pinus virginiana*?
Papaipema marginidens	a borer moth		SU	
Parahypenodes quadralis	a noctuid moth		SU	dead leaves or fungi
Renia sp. 1 nr. *discoloralis*	a noctuid moth		S1	
Richia acclivis	a noctuid moth		S1S2	
Sutyna privata teltowa	a noctuid moth		S2S4	*Smilax*?
Tolype notialis	tolype moth		S1	
Xestia elimata	southern variable dart moth		S2S3	
Xylotype capax	barrens xylotype		S3	*Vaccinium*
Zale curema	a zale moth	G3G4	S1	*Pinus virginiana*?
Zale obliqua	oblique zale moth		S1	*Pinus virginiana*?
Zale squamularis	a noctuid moth		S2S3	*Pinus virginiana*?
Zale submediana	a zale moth		S2	*Pinus virginiana*?
Zanclognatha martha	Pine Barrens zanclognatha		S1S2	*Pinus* (dead leaves)

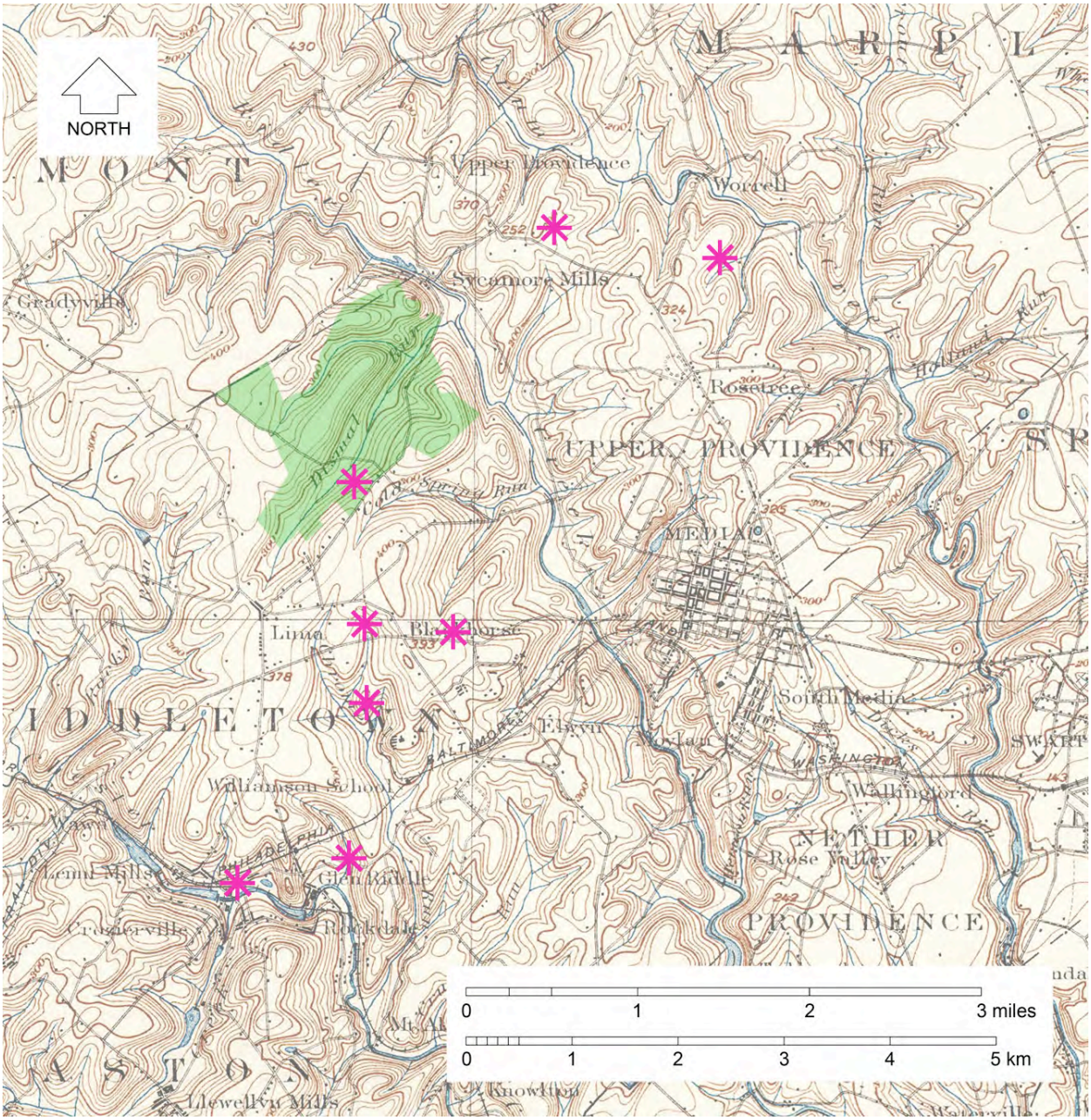


Figure 2. **Locations of Pink Hill and the other seven historical sites of the Middletown-Upper Providence serpentine barrens cluster**[1] (pink stars) and the present-day Tyler Arboretum (green shading) are superimposed on a topographic map published in 1898[2].

[1] Harshberger 1903; Pennell 1910, 1912
[2] Chester, Pennsylvania, 15-minute quadrangle, U.S. Geological Survey, Washington, D.C.

Geological setting and significance

With its unusual vegetation and soils so thin in places that the bedrock is exposed to view, Pink Hill marks a geological feature of great significance that elsewhere is hidden beneath thick soils and vegetation. The barrens' northwestern edge traces a small part of the suture line between one-billion-year-old rock of the North American continental plate (gneiss) and much younger oceanic basement rock (amphibolite and serpentinite), raised up and perched during the annihilation of an offshore island arc in the collision of Africa with North America[1].

The earth's crust is divided into gigantic pieces called tectonic plates, which float atop the molten interior and move around very slowly. They cover the planet's entire surface, so the edges between moving plates are subject to enormous forces. Plate edges are some of the most geologically dynamic areas on earth. Some are mid-oceanic ridges or rift valleys, where new rock is forming as molten material wells up from the depths. At some edges the plates are slipping past each other, for instance, at the San Andreas Fault between the North American and Pacific plates. Other edges are subduction zones, where one plate is sliding beneath another. Pink Hill marks a subduction zone that was active a half-billion years ago, when a plate that is now gone was being squeezed between the converging African and North American plates.

This titanic event occurred slowly, over tens of millions of years, obliterating the Iapetus Ocean, a predecessor to the Atlantic. During the breakup and subduction of the oceanic basement rock, a few pieces piled up along the continental margin. In the process they underwent chemical and physical transformations, changing from igneous peridotite and pyroxenite into metamorphic amphibolite and serpentinite. A lofty mountain range was thrust up as the continents and the islands between them crashed together. Hundreds of millions of years of erosion eventually obliterated the mountains, bringing the rock that had lain deep within them to the surface by lowering the surface itself until the mountains' core was exposed.

A jumble of various rock types underlies Pink Hill and the surrounding woods. All are products of metamorphosis during the collision under fluctuating heat and pressure in the presence of seawater. Rocks solidified, remelted and resolidified and minerals crystallized, dissolved and recrystallized differently from one spot to another depending on local temperatures and how much water was present[1]. Some of the rock is a mottled green—the magnesium-rich "serpentine stone" used at one time as a decorative building material. In other places the serpentinite was fractured and the cracks filled with silica-rich water that gradually precipitated to form veins of quartz. Some of the serpentinite has partly dissolved away, leaving the less soluble quartz and iron oxides behind to form a brown rock filled with irregularly shaped holes, known as honeycomb rock[2].

The geology of the Middletown serpentinite formation has influenced economic activity in other ways besides making it impractical to grow crops where soils are thin and the bedrock is close to the surface. Pockets of limonite—shiny black nodules in the interstices of the honeycomb rock just west of Pink Hill—were for a short period in the nineteenth century mined as a low-quality iron ore; after smelting it was still high in silicon, which rendered it too brittle to be of much use[3]. At nearby Chrome Run (just south of Riddle Memorial Hospital), nuggets of chromite were plentiful enough to supply a chromium-refining industry in the early to mid-nineteenth century, mainly to supply yellow pigment for paint[4].

[1] Steve Phipps, personal communication (2008)

[2] Smith 1862

[3] Roger Mitchell, personal communication (2008)

[4] Pearre and Heyl 1960

Figure 3. **Changes since 1937 in the area of serpentine grassland at Pink Hill** based on interpretation of aerial photography[1], overlain on 2005 aerial imagery[2]. Painter Road is at top; Barren Road is at lower right; green line is the Tyler Arboretum boundary.

[1] 1959–2005: Tim Dougherty, Joy Fritschle, Pedro Garaitonandia, Scott Greenly and Joan Welch; 1937: Roger Latham

[2] Delaware Valley Regional Planning Commission 2007

Historical background

The earliest written mention of serpentine vegetation in Pennsylvania uncovered so far, in 1745, was likely inspired in part by the barrens in and near Middletown Township and might well have reflected familiarity by its author with Pink Hill itself. It was part of a letter dated December 6th of that year from the Philadelphia botanist John Bartram (1699-1777), the first botanist of European descent born in the Americas, to the Dutch naturalist John Frederic Gronovius:

> Ye Loadstone [magnetite] lieth in a vein of a particular kind of stone that runs near east and west for sixty or seventy miles or more, appearing even with, or a little higher than its surface, at three, five, eight, or ten miles distance, and from ten to twenty yards broad, generally mixed with some veins of cotton [asbestos]. Ye earth of each side is very black, and produceth a very odd, pretty kind of *Lychnis* [moss phlox], with leaves as narrow and short as our Red Cedar, of humble growth, perennial, and so early as to flower, sometimes, while the snow is on the ground; also a very pretty *Alsine* [barrens chickweed]. Hardly anything else grows here. Our people call them Barrens ...[1]

Later botanists paid regular visits to Pink Hill, collecting plant specimens that they pressed, mounted and labeled for deposit in scholarly herbarium collections. Some specimens collected at Pink Hill well over a century ago can still be examined at the herbarium at the Academy of Natural Sciences of Philadelphia. John William Harshberger (1869–1929), professor of botany at the University of Pennsylvania from 1893 until his death in 1929, brought his botany classes to Pink Hill on field trips and mentioned the site by name in the first scientific piece ever published on the subject of eastern serpentine grasslands, in a 1903 issue of the journal *Science*[2]. Francis Whittier Pennell (1886–1952), curator of botany at the Academy and

John Bartram (illustration by Howard Pyle in his article "Bartram and His Garden," *Harper's New Monthly Magazine* **60**: 321-330, February 1880)

the foremost twentieth-century botanical authority on Pennsylvania's serpentine barrens, first visited the site in 1908[3]. Edgar

[1] Berkeley and Berkeley 1992: pages 265-266
[2] Harshberger 1903

[3] Herbarium records (Pennsylvania Flora Project database, Morris Arboretum of the University of Pennsylvania, courtesy of Tim Block and Ann Rhoads)

Theodore Wherry (1885–1982), professor of botany at the University of Pennsylvania from 1930 to 1955, had a special interest in Pink Hill that dated back to his undergraduate days as a chemistry major at Penn, when—most likely due to Dr. Harshberger's influence—he was intrigued by the seeming affinity of moss phlox for soils derived from serpentinite bedrock[1].

Unfortunately, no published botanical description of the barrens flora at Pink Hill by any of the early botanists has been found. A simple species list can be gleaned from papers published in 1910 and 1912 by Dr. Pennell (see Appendix), but clues about their relative abundances and the structure of the landscape and ecosystem are lacking. Minshall Painter, who established the Painter Arboretum, the nucleus of the Tyler Arboretum, was also surprisingly uncommunicative on the subject, at least in the writings he left behind.

The Painter brothers, Minshall and Jacob, were born (in 1801 and 1814, respectively) on the property that was to become the Tyler Arboretum. They eventually inherited it from their mother, Hannah (Minshall) Painter (1782–1838), who had inherited it in a direct line from her great-great-grandfather, Thomas Minshall (1652–1726), the original William Penn grantee of the tract. The brothers lived there until they died at ages 72 and 63. Minshall Painter was renowned as a botanist, horticulturist and student of nature:

> Although actively engaged as a farmer and miller, he devoted at least one day a week to long tramps over the surrounding country. He took notes on everything he could see, and collected plants, minerals and insects. His herbarium included nearly all of the flowers of this part of the country and many from other places.[2]

Surprisingly, despite his botanical expertise and the sophistication of the arboretum collection that he started, Minshall Painter evidently left no written description of the primeval botanical treasure that he, in later years, owned. From his early 20s he wrote almost daily entries in a daybook but made only passing reference to the barrens and to quarrying the serpentine stone next to the bridge over Dismal Run[3]. For instance, on the 14th of April 1823 he mentioned an employee "*cutting white oak on barrens—Turmericks out in bloom*" (it is uncertain what he meant by "Turmericks" but the early spring date suggests that it likely was moss phlox). He recorded spending part of the 26th and 27th of May 1832 "*out botanizing on barrens*." On the 19th of August the following year, "*Commenced building the bridgeway [on the barn]—getting out stone on the barrens*." In December 1856, "*Examined wood for sale to Isaac Chalfant on the barrens—1 cord hickory wood, 2½ oak wood*"; March 1861, "*cutting ceders [sic] on the barrens for vines to run over*"; August 1861, "*cutting down chesnut [sic] trees on barrens that are dying[,] for rails*." About once a year from 1863 to 1870 he mentioned quarrying stone or digging for minerals on the barrens[4].

In an 1870 map of Delaware County landholdings, a tract of about 10 acres—the portion of Pink Hill adjacent to Barren Road—is shown as belonging to a T. Ford and containing a building next to the road. It was surrounded by the Painter brothers' property[5]. Before another landholdings map was published in 1875, the Painters must have acquired the Ford tract, perhaps before Minshall's death in 1873. By 1875 the Middle Farm—between the present-day Pinetum and Rocky Run—had been conveyed to the Painter brothers' niece Ann Tyler but Jacob (who died in 1876) still owned the eastern and western portions of what was to become the Tyler Arboretum, including Pink Hill and the building on the former Ford tract[6]. No trace of the building is obvious today.

[1] Wagner 1982
[2] Conard 1914: p. 20
[3] Pam Harper, personal communication (2008)
[4] All quoted entries transcribed and compiled by Pam Harper
[5] Hopkins 1870
[6] Everts & Stewart 1875

John W. Harshberger on 7 May 1904 with a University of Pennsylvania botany class at Pink Hill, with moss phlox (*Phlox subulata*) in full bloom (photo by Elizabeth R. Allen; courtesy of the University of Pennsylvania Archives)

Professor Harshberger (University of Pennsylvania Archives)

A series of large pits in the woods just southwest of Pink Hill is all that remains of a nineteenth-century mining enterprise, extraction of limonite deposits for smelting into iron. An 1875 Atlas of Delaware County labeled the precise location of the pits as "*Iron Mine*"[1]; the owner and operator was John Smedley[2]. Soil derived from iron oxide-rich, bright orange, highly weathered honeycomb rock dug out of some of the pits and now mounded around their rims is an almost pure clay of a striking deep red or maroon color. People in traditional societies worldwide use such clays to make decorative fired clay objects and—slightly refined into red ochre—as a dye or paint or as a face or body decoration. Clays of such a vivid shade are rare in this part of the Piedmont[3], suggesting that Indians might have used the Pink Hill area in prehistoric times as a source of at least one valued commodity, red clay; another prized commodity, jasper (colorful, iron-rich quartz used to make tools and ceremonial objects), was quarried in prehistoric times just ¾ mile south of Pink Hill[4].

The distinctive flora of Pink Hill almost certainly was maintained for centuries or thousands of years by Native Americans using fire to manage the local landscape (see discussion on page 4). After the Indians' departure, the barrens would in all likelihood have been lost to forest succession if it were not sustained by a different chronic disturbance, namely, livestock grazing. As one commentator put it in a 1959 issue of *John J. Tyler Arboretum Bulletin*[5]:

> We are told that the hill was at its best when it was grazed. The robust tall grass that covers the upper part of the open area looks like a tough rival to the lowly Pink, and perhaps the horses and cows aided the Pink in [by] eating the grass.

Some Arboretum visitors also contributed a type of vegetation disturbance, but it was one that had an adverse affect on at least one esteemed member of the serpentine flora. From the same 1959 issue of the *Bulletin*[5]:

> Truckloads and carloads of Mountain Pink were dug and carted away. Even now there is some digging, although less than there was. Culprits caught in the act are apt to come up with the curious explanation that they "didn't know the plants belonged to anyone."

The Tyler Arboretum has the distinction of being the pioneer of serpentine grassland management, using fire long before the practice was adopted in the mid-1990s by The Nature Conservancy (at several sites in Pennsylvania and Maryland) and the Maryland Department of Natural Resources (at Soldiers Delight near Baltimore), and more recently by Natural Lands Trust and the Pennsylvania Department of Conservation and Natural Resources' Bureau of Forestry, among others. Although there was no thought of using fire as a management tool during John Caspar Wister's tenure as the Arboretum's first Director[6] (1946–1968), Arboretum staff began burning in the grassland in the 1970s[7], perhaps at the urging of Dr. Wherry. At the Arboretum's invitation, the Middletown Township fire companies (Lima, Middletown and Lenni Heights) burned parts of the grassland as a training exercise several times beginning in 1985[8]. Various people recall accidental or arson fires in the barrens, for instance, one in the late 1970s[9] and one in 1995[8], but the fire company keeps records for only five years so accurate knowledge of any previous wildfires is lost[8]. The Nature Conservancy conducted a prescribed burn in 2004 and Natural Lands Trust did so in 2008.

[1] Everts & Stewart 1875
[2] Roger Mitchell, personal communication (2008)
[3] Art Johnson, personal communication (2008)
[4] Heather Wholey, personal communication (2008)
[5] Anonymous 1959, p. 2
[6] George Longenecker, personal communication (2008)
[7] Carl Suk, personal communication (2008)
[8] Chuck Phillips, personal communication (2008), including information relayed from Jack McKeown and Brian Lank
[9] Sladky 1981

Restoration and Management

Pink Hill is a natural resource with significance well beyond the borders of Pennsylvania and surrounding states, with its unique combination of geological and biological assets. The site has a rich history, including the remarkable story of how the serpentine barrens ecosystem and its exceptional diversity of native species have been sustained even in the face of changing cultural practices. Despite the decline of its grassland area in the last 71 years from almost 14 acres to about 3 acres, Pink Hill's remnant serpentine grassland remains a significant and valuable example of a globally rare ecosystem.

However, the rare species living at Pink Hill are critically endangered by the delayed effects of severe losses in habitat area. Several rare, barrens-restricted species have died out already. Management of the remaining grassland has arrested its acreage decline but native grassland species are expected to keep vanishing as the effects of the drastic loss in habitat area continue to unfold. Extending management into known areas of former grassland would increase the ecosystem's capacity to sustain its extraordinary species diversity and even to reinstate lost species, if they can be translocated from other sites in the region where remnant native populations still exist.

The grassland at Pink Hill has already declined to a critically small total size. The losses are particularly momentous in light of the fact that the rest of the Middletown Barrens have been permanently eradicated. Further losses of rare plant and animal species are assured unless the decline is not just halted but substantially reversed. The highest-priority goal of the management program is restore the grassland to more than triple its current size.

Desired future condition

Desired future condition analyses are an important component of the science-based approach to ecosystem management developed by the U.S. Forest Service, National Park Service, and other conservation agencies and organizations. The process ties together adaptive resource management, ecological restoration, master planning, ecosystem monitoring and outcomes assessment. A desired future condition statement is a qualitative and quantitative description of *ecosystem attributes* that are expected to be present at some point in time as an outcome of deliberate management policies, strategies and practices. Ecosystem attributes include individual resources, communities, ecosystems and the natural processes that sustain them. A desired future condition is not an attempt to return to the past, but takes into account both what is known about the pre-degradation condition and important influences that have been added or taken away since then and are beyond managers' control.

Striving toward ultimate goals and the quantitative objectives related to those goals calls for many steps—small, medium, and large—before the goals are met. Setting those goals and objectives provides a yardstick to measure the value of steady progress. Success comes not only when an objective is achieved in full measure, but also in reaching various mileposts along the way.

The next few paragraphs briefly paint a word picture of what Pink Hill might look like twelve years from now and a sketch of the institutional structures that could help achieve and sustain that condition.

Physical components

By 2020, the grassland covers over 10 acres from the slope along Dismal Run nearly to Barren Road. It is a structurally diverse mosaic, with a mix of large patches of mainly warm-season grasses, small patches of thin soil with a sparse cover of native forbs and annual grasses, scattered clumps of dwarf ericaceous shrubs, and areas dotted with isolated trees, mainly blackjack oaks with a few post oaks, bush oaks, scarlet oaks, eastern red-cedars and Virginia pines. Greenbriers are a decidedly minor component of the mix, growing mainly along the grassland-forest edge. Black locust, ailanthus and autumn-olive are nowhere to be seen. Japanese stiltgrass, oriental bittersweet, multiflora rose and Japanese honeysuckle—once rampant along the northern edge of Pink Hill near Dismal Run—have been almost entirely replaced by native grassland species, some of which are moist-soil indicators. Populations of Japanese barberry, multiflora rose, Japanese honeysuckle and other invasive species once common in the surrounding woods are stable at insignificant levels.

The diversity of native grassland species is higher than ever in the recorded history of Pink Hill. Scattered sites within the 7–9 acres of restored grassland have been planted with plugs reared from seed—collected at remnant serpentine barrens in Chester County—of species that were once part of the flora of Pink Hill and other sites in the historical local cluster of serpentine barrens. Vulnerable species including Philadelphia wood lily, blackjack oak, slender ladies'-tresses, spring ladies'-tresses, colic-root and striped gentian are thriving and reproducing once again, as the deer population in the area surrounding Pink Hill has been reduced and is being maintained at a level that allows some individuals to set seed each year.

Monitoring has tracked fluctuations between years and over longer time periods in the populations of key plant species, mostly within the ranges of variation established as no cause for alarm. Such ups and downs in population levels over time are expected to continue indefinitely as normal, inevitable features of a functioning ecosystem, which is always dynamic and involves interactions and feedbacks among its myriad organisms and other components that are highly complex, ruling out precise prediction.

Institutional components

Staff members and others involved in management have a strong appreciation that variation in the extent and timing of disturbances (fire, drought, herbivore outbreaks) is not only unavoidable but desirable, being part of the basis for the maintenance of genetic diversity, species diversity, structural diversity (vegetation layers within a patch) and landscape diversity (patches of different species composition, soil conditions and disturbance history across the site). The routine management program includes a prescribed burn of 3–4 acres once every 2–3 years in rotation around the site, with fire return intervals varying from place to place in the range of 3–12 years. Annual management also includes spot-control of invasive species using methods appropriate to the species and site conditions (e.g., spot-herbiciding, hand removal by volunteers, mechanical removal of root systems and the upper organic soil layer) and, where the soil would support the reestablishment of the invasive plants, planting seeds or plugs of native species in the gaps.

Permanently marked monitoring transects and plots are scattered across the remnant grassland (3 acres), the restored grassland (the peripheral and southern 7–9 acres), and the woods edges. An Arboretum staff member hires and trains summer interns every year to collect monitoring data in coordination with a conservation biologist partner or consultant, who annually updates the monitoring design to keep pace with current needs, analyzes the data, and works together with Arboretum management staff to reconsider management methods based on the results and make adjustments where necessary. The Arboretum continually cultivates longstanding

relationships with scientists at West Chester University, Swarthmore College, University of Pennsylvania, University of Delaware, Academy of Natural Sciences of Philadelphia and other regional institutions that maintain a steady flow of faculty and student research projects at the barrens, some of which are designed in coordination with the Arboretum to produce results pertinent to serpentine grassland conservation at Pink Hill.

The Tyler Arboretum has been a pioneer in the use of prescribed burning to sustain the fire-dependent serpentine grassland ecosystem.

Focal conservation targets and restoration/management objectives

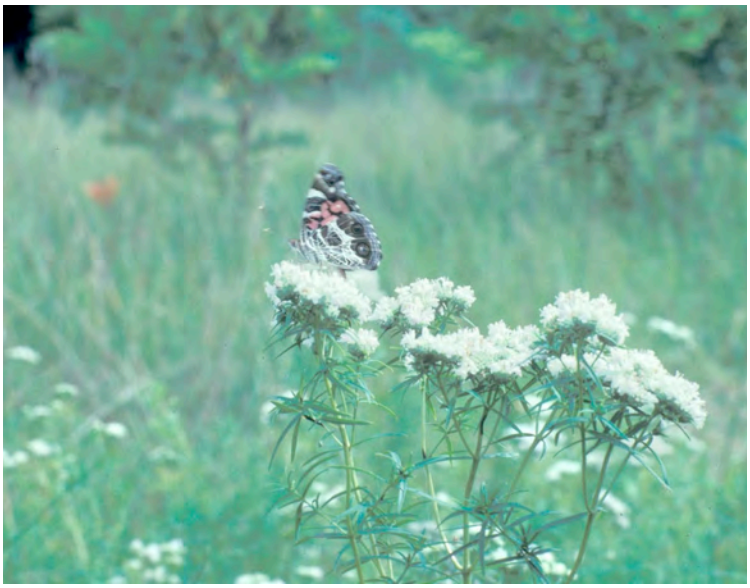
Focal conservation targets are a limited suite of species, communities and ecosystems chosen to represent and encompass the full array of biodiversity found in an area. According to The Nature Conservancy's *Conservation Action Planning Handbook*,

> they are the basis for setting goals, carrying out conservation actions, and measuring conservation effectiveness. In theory, conservation of the focal targets will ensure the conservation of all native biodiversity within functional landscapes. … The coarse filter/fine filter approach is a useful framework for selecting focal conservation targets. Coarse filter targets are those ecological systems or community types or occasionally species that, when conserved, also conserve a larger suite of species within the project area. The species and natural communities that would be conserved by protecting a coarse filter target can be described as nested targets. The fine filter is composed of species and communities that are not well captured by coarse filter targets and require individual attention. These targets may be rare, face unique threats or require unique strategies.[1]

Grassland birds have been receiving much attention in the conservation community and it is worth mentioning why they are not included in the list of focal conservation targets for Pink Hill. The term "grassland birds" refers to grassland-obligate or grassland-interior species; in order to nest and successfully rear young they need access to large grasslands or meadows or to habitats that supply the same nesting cues and resources. Pennsylvania's

[1] The Nature Conservancy 2007: pages 16, 17

breeding bird fauna includes 15 such species; two are classified as endangered and five as threatened or candidates at risk and nearly all have undergone serious declines in recent decades. In our region, grasshopper sparrow, savannah sparrow, vesper sparrow, eastern meadowlark, bobolink, horned lark and northern bobwhite populations have become imperiled due to the decline in native grasslands and meadows. As a rule of thumb in the Mid-Atlantic region, grassland or meadow patches of 12 to 25 acres sometimes support one or a few breeding pairs of a single 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 open habitat, unbroken by hedgerows and with few trees, to support multiple grassland-obligate bird species[1]. When fully restored, Pink Hill's grassland is expected to cover 10–12 acres. It may support some small spillover of nesting grassland birds from the larger meadows in the center of the Arboretum but it is unlikely to attract a self-sustaining population on its own.



Serpentine grasslands are prime butterfly habitat. Here a painted lady sips nectar from a narrow-leaved mountain-mint at Pink Hill.

Pink Hill is fully capable of providing habitat for grassland and meadow species that do not require large, unbroken blocks. Prime examples are many species of declining or imperiled butterflies and moths. Native meadows and grasslands of just a few acres can provide habitat for these and other rare species. The restored grassland at Pink Hill will also perform the important function of increasing overall biological diversity at a local (neighborhood) scale. Many wildlife species whose populations are still secure in the region but are seen less and less often with increasing suburban sprawl can thrive in a 10-acre grassland. Among 43 butterfly species in this category reported to live in Pennsylvania serpentine barrens[2] are monarch, great spangled fritillary, Aphrodite fritillary, question mark, comma, mourning cloak, red admiral, painted lady, American copper, black swallowtail, eastern tiger swallowtail and falcate orange tip. Birds include American kestrel, red-tailed hawk, yellow-shafted flicker, barn swallow, tree swallow, northern rough-winged swallow, eastern bluebird, eastern kingbird, purple martin, house wren, cedar waxwing, indigo bunting, American goldfinch, song sparrow, chipping sparrow and field sparrow. A key intended effect of the focal conservation target approach is that many other native populations and communities in addition to those chosen as focal targets will benefit.

The focal conservation targets are:

1. **Globally rare ecosystem: serpentine grassland**
2. **Globally rare species: serpentine aster**
3. **Other plant species of special concern**
4. **Host plants of insect species of special concern**

[1] Peterjohn 2006

[2] Anderson 1971

Globally rare ecosystem: serpentine grassland

NatureServe, the parent organization of all of the states' natural heritage programs (and throughout the Western Hemisphere), ranks eastern serpentine grassland G2, which means it occurs in only 6–20 locations altogether and is imperiled throughout its range because rarity, steep decline and other factors confer high vulnerability to total loss. The grassland at Pink Hill is one of about 18 surviving serpentine grasslands in the entire range of eastern serpentine barrens from southeastern Georgia to southeastern New York.

Table 3. **Serpentine grassland—status, objectives and indicators**

key ecological attribute	current status	objective (with acceptable range of variation)	measurable indicator(s)
Size	~12,000 m^2 out of a documented historical extent in 1937 of ~55,000 m^2	Contiguous expanse of 50,000 m^2 (12 acres)	Area measured from recent satellite photos using GIS or by counting squares on graph paper overlay
Dominance by native grasses and forbs	Within desired range in 12,000-m^2 remnant grassland only	50%–75% total cover of native grasses and 75%–95% aggregate cover of native grasses and forbs	Estimated cover, extrapolated from data collected on widely dispersed, permanently marked transects and quadrats
Sparse tree cover	Within desired range in 12,000-m^2 remnant grassland only (except that post oak is missing and presumed extirpated)	5%–25% total tree cover with high dispersion (not clumped); trees mainly blackjack oak and post oak	Area measured from recent leaves-on satellite photos using GIS or by counting squares on graph paper overlay
Diversity of native plant species documented historically at Pink Hill and nearby that are characteristic of serpentine grasslands or are uncommon	27 populations confirmed present in 2000—24 evidently reproducing (in some cases at low levels) and 3 whose seed output or seedlings are eradicated by overabundant deer	Number of reproducing populations of species listed in Appendix in categories 4–10: • 30 is minimal • 45 shows significant progress • 60 is the goal	Estimated population sizes (order-of-magnitude precision is adequate) and confirmation of reproductive status based on annual surveys
Patch (community) diversity	Within desired range in 12,000-m^2 remnant grassland except in moist-soil patches, which are dominated by nonnative invasive species	Vegetation includes: • multiple treeless areas of various sizes • moist-soil patches dominated by native species • sparsely vegetated areas with exposed bare gravel	Species percent cover data collected on appropriately located, permanently marked transects and quadrats Area measured from recent leaves-on satellite photos or estimated on the ground

Globally rare species: serpentine aster

Serpentine aster (*Symphyotrichum depauperatum*) is ranked G2, signifying that it occurs in only 6–20 locations altogether and is imperiled throughout its range because rarity, steep decline and other factors make it highly vulnerable to extinction. It is thought to be the only globally rare plant species present at Pink Hill or recorded historically throughout the central Delaware County serpentine barrens complex (although additional globally rare species are present at several of the other remaining serpentine barrens).

Table 4. **Serpentine aster—status, objectives and indicators**

key ecological attribute	current status	desired status (with acceptable range of variation)	measurable indicator(s)
Number of plants	Roughly estimated at 500–1,000 but needs more systematic investigation	1,000–10,000 over 50,000-m^2 expanded grassland area	Rough estimate based on extrapolation from counts in small areas is adequate
Number of discrete patches	Roughly estimated at 10–15 but needs more systematic investigation	25–50 over 50,000-m^2 expanded grassland area	Rough estimate based on field survey is adequate
Total area of patches	Roughly estimated at 200–400 m^2 (1½%–3% of existing grassland)	600–1,200 m^2 over 50,000-m^2 expanded grassland area	Rough estimate based on field survey is adequate

Extant and extirpated plant species of special concern

According to current rankings of species of special conservation concern by the Pennsylvania Biological Survey and the Pennsylvania Natural Heritage Program, 10 species besides serpentine aster that are present or known historically at Pink Hill have official status in the state, classified as PE (endangered), PT (threatened), PR (rare) or TU (status tentatively undetermined and under study).

Indian paintbrush, a threatened species in Pennsylvania, is among nearly 100 native grassland species that once occurred at Pink Hill but died out during the grassland's decline in area, from nearly 14 acres 70 years ago to just 3 acres today. All are candidates for reintroduction using seed collected from nearby intact populations.

Table 5. **Other plant species of special concern—status, objectives and indicators**

key ecological attribute	current status	desired status (with acceptable range of variation)	measurable indicator(s)
Population status of colic-root (PE)	Not found in 2008 survey	100–1,000 widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of arrow-feather three-awn (PT)	Sparse in 12,000-m^2 remnant grassland	1,000–10,000 widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of Indian paintbrush (PT)	Not found in 2008 survey	100–1,000 widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of annulus panic grass (PT)	Not found in 2008 survey	1,000–10,000 in sparsely vegetated areas and widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of Heller's witchgrass (TU)	Probably within desired range, in 12,000-m^2 remnant grassland only	1,000–10,000 widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of annual fimbry (PT)	Not found in 2008 survey	100–1,000 in moist-soil patches and sparsely vegetated areas	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of soapwort gentian (PE)	Not found in 2008 survey	100–1,000 in moist-soil patches	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat

(continued on next page)

key ecological attribute	current status	desired status (with acceptable range of variation)	measurable indicator(s)
Population status of Appalachian groundsel (PR)	Probably within desired range, in 12,000-m^2 remnant grassland only	1,000–10,000 widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of showy skullcap (PE)	Not found in 2008 survey	100–1,000 widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of spring ladies'-tresses (PE)	Not found in 2008 survey	50–500 widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat

Host plants of insect species of special concern

Of insect species in Pennsylvania serpentine barrens, which may number in the thousands, 47 Lepidoptera (butterfly and moth) species documented at one or more of the barrens are ranked by the Pennsylvania Natural Heritage Program as species of special conservation concern. No surveys of Lepidoptera or other broad animal groups have been conducted at Pink Hill. Only one rare insect species has been confirmed (it is not a butterfly or moth)—the globally rare moss phlox mirid (*Polymerus tinctipes*), a specialist feeder on its namesake plant[1]. Of the rare grassland Lepidoptera in the region whose larval host plants are known (see Table 2), some of the most highly ranked in terms of global rarity depend on host plants that are present or occurred historically at Pink Hill. Two host plant species and one group of related host plants stand out. The mottled duskywing (*Erynnis martialis*; G3G4[2]), an unnamed geometer moth (*Apodrepanulatrix liberaria*; G4), broad-lined erastria moth (*Erastria coloraria*; G4) and northern spring azure (*Celastrina ladon lucia*) feed on New Jersey tea. The frosted elfin (*Callophrys irus*; G3) and persius duskywing (*Erynnis persius persius*; G5T1T3[3]) feed on wild indigo. The arogos skipper (*Atrytone arogos arogos*; G3T1T2[3]), dusted skipper (*Atrytonopsis hianna*), Indian skipper (*Hesperia sassacus*) and swarthy skipper (*Nastra lherminier*) feed on little bluestem and other serpentine barrens grass species.

[1] Wheeler 1995

[2] See Table 2 caption for interpretation of G-ranks.

[3] T-ranks refer to the degree to which a *subspecies* is globally imperiled; the range within a subspecies' T-rank indicates that more information is needed.

Table 6. **Host plants of insect species of special concern—status, objectives and indicators**

key ecological attribute	current status	desired status (with acceptable range of variation)	measurable indicator(s)
Population status of moss phlox	Within desired range in 12,000-m^2 remnant grassland only	Minimum cover of 5% of total grassland area in patches widely distributed over 50,000-m^2 expanded grassland area (2,500 m^2)	Rough estimate based on field survey is adequate
Population status of New Jersey tea	Population small—roughly estimated at 100-1,000 stems covering 100–200 m^2	500–5,000 stems widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of wild indigo	Not found in 2008 survey	500–5,000 widely distributed over 50,000-m^2 expanded grassland area	Counts on appropriately located, permanently marked transects and quadrats, supplemented by random-walk rough counts in remainder of habitat
Population status of little bluestem	Within desired range in 12,000-m^2 remnant grassland only	Abundant (over 1,000,000 stems) and widely distributed over 50,000-m^2 expanded grassland area	Rough estimate based on field survey is adequate

Threats

Threats are stresses on conservation targets and their sources. A stress is a process or event with direct negative consequences on the conservation target (e.g., forest succession at the grassland edge). A source (stressor) is the action or entity that produces a stress (e.g., fire exclusion). Threat analysis involves identifying and ranking stresses and stressors for each of the conservation targets. In ranking threats, several factors are taken into account:

- Severity of damage—What level of damage can reasonably be expected within 10 years under current circumstances if they do not change?
- Scope of damage—What is the geographic scope of impact on the conservation target within the project area that can reasonably be expected within 10 years under current circumstances if they do not change?
- Irreversibility of damage—How responsive is the conservation target likely to be to corrective action after the damage is done?

The principal threats to the focal conservation targets identified in the previous section, in rank order of severity, scope and irreversibility of the consequences, are:

1. **Critically low population numbers associated with habitat area decline**
2. **Fire exclusion and forest succession**
3. **Nonnative invasive species**
4. **Artificially elevated white-tailed deer population**

Critically low population numbers associated with habitat area decline

Nearly 80% of the 1937 grassland area has been lost to forest succession (see Figure 3). The losses were accelerating before invasive woody plant control and the resumption of prescribed burning in the last five years. Acceleration of area loss is typical as a habitat "island" shrinks over time. It is a simple fact of plane geometry that the edge-to-area ratio increases as a remnant patch of grassland is squeezed and fragmented by invading woody plants; shrink any two-dimensional shape and its area declines faster than the total length of its perimeter. In patches of serpentine grassland, the edges are where the invading plants creep in from the protective partial shade and ever-increasing soil organic matter at the forest border. The longer the perimeter relative to the interior, the faster a patch of grassland dwindles. Without constant renewal by the types of disturbances that have sustained the grasslands throughout their history, the remaining patches shrink at mounting speed.

As the area of each grassland patch declines, the population numbers of all of the native plant and animal species that depend on grassland habitat also fall off. Wild plants and animals don't have the option of responding to decreasing living space by crowding together. The amount of territory, food and other land-based resources each individual needs is a characteristic of its species. As numbers drop, all species become more vulnerable to local extinction. Wild populations fluctuate as a matter of course with year-to-year differences in weather, predator abundance, disease outbreaks, and other factors. When populations are small, their chances of dipping to zero during normal fluctuation greatly increases. There is no recovery from zero population.

Small, isolated populations are especially vulnerable to disaster from causes such as disease, prolonged drought, or a management error based on inadequate knowledge. An example is the heath hen, a wild cousin of the prairie chicken that once lived in Pennsylvania's serpentine barrens. Soon after European settlement of the Northeast the species dwindled catastrophically due to hunting pressure. By the early twentieth century, it survived only on Martha's Vineyard, Massachusetts, where it was protected and considered to be secure. But, ironically, the decision by wildlife managers to protect its habitat from fire most likely sealed its fate. The dwindling of grasslands and heathlands on Martha's Vineyard due to an absence of the fires that had sustained them for centuries aggravated the population's decline. When the last individual on Martha's Vineyard died, heath hens became extinct.

The extirpation—local extinction—of native species has already happened over the last 50 to 100 years at Pink Hill. At least 93 plant species documented as occurring historically in the grassland there were not found in a 2008 survey (see Appendix, species list categories 5 and 6 and Table A). The situation is even worse when the entire Middletown-Upper Providence cluster of serpentine barrens is included. Considering just rare species alone, of the 37 plant species classified as endangered, threatened or rare that have been reported since around 1900 at the eight sites, 33 have not been seen in recent years and are probably gone (see Table 1). It is safe to assume that grassland-dependent invertebrate species, which have never been comprehensively surveyed at Pink Hill, have declined at even higher rates, because animal populations are generally more sensitive and quicker to respond to habitat loss than plants.

For thousands of years, when a wild population was extirpated from one of the local group of serpentine barrens, the species had a chance of regaining its lost foothold by chance recolonization from one of the other sites in the group. Ecologists term this the *rescue effect*. Now that all of the serpentine grasslands that once ringed Pink Hill have been eradicated by development, any spontaneous "rescue" of extirpated species is highly unlikely. It is more crucial than ever

that extirpation be prevented from occurring in the first place.

Fire exclusion and forest succession

Except for salt marshes along the Atlantic coast, most long-persisting (dating from before European settlement) native grasslands in the mid-Atlantic region owe their existence and long-term maintenance to fire[1]. This principle has been recognized for a long time with respect to some grassland ecosystems, but apparently it was first connected to serpentine grasslands in particular less than 30 years ago[2]. The peculiar qualities of serpentine soil were thought to be enough to explain the unusual vegetation until some botanists and ecologists in the mid-twentieth century began to notice that the serpentine grasslands were shrinking and disappearing. The losses were not all due to conversion to golf courses and housing developments; in many cases the culprit was simple forest succession, starting at the edges of the grasslands.

The reasons why succession suddenly began taking its course in the mid-twentieth century after years of suspension are twofold. First, increasing human population density in the area, together with advancing technology, led to effective wildland fire control for the first time in history. For the 2½ centuries before then, fires in remote areas were allowed to burn themselves out—rural residents had no choice in the matter. Secondly, increasing human population density was accompanied by the abandonment of farms and the end of livestock grazing.

Also critical to the connection between fire and the persistence of remnant serpentine grasslands over long time periods are two effects of severe soil conditions and severe summertime heat in the barrens—slowing plant growth and increasing plant mortality. The harsh conditions kill many trees at the seed or seedling stage and cause the few survivors to grow quite slowly, with the exception of black locust and sassafras root suckers (trees originating as root sprouts), whose needs are subsidized via rhizomes (underground runners) connected to their full-grown parents at the woods edge. The result is that grasses and forbs, which are more tolerant of these conditions, can maintain their dominance longer between tree-killing disturbances in serpentine barrens than in other kinds of grasslands, meadows and abandoned farm fields. This is why burning maintains serpentine grassland even if fires occur seldom and sporadically. Most grasslands and meadows in the region would need to burn much more often and on a more regular schedule to prevent forest succession.

The chief forest trees currently invading the grassland edges are red maple, sassafras and Virginia pine. Black locust and ailanthus are nonnative, weedy trees that also are invasive at Pink Hill (black locust, even though it is native to parts of eastern North America, did not occur east of the Appalachians at the time of European contact; ailanthus is from eastern Asia). Common greenbrier is a native woody vine that prefers wet habitats or shade, but a greenbrier living in partial shade and organic-matter-rich soils at the forest edge or under a large, isolated tree can send rhizomes out into the open grassland and grow a thicket there to harvest light rays, secondarily shading out the grasses and forbs. Trees and greenbriers that successfully invade the grassland drop large quantities of organic matter in dead leaves, bark and branches. The buildup of soil organic matter eventually buffers plant life in the vicinity against the effects of serpentine mineral soil, gradually converting barrens into species-poor forest, which exterminates grassland species by shading them[3].

Nonnative invasive species

Black locust was noted as the chief invasive species threat to the grassland by Dr. Wherry[4], probably as early as the mid-1950s.

[1] Day 1953; Thompson and Smith 1970; Denevan 1992; Latham and Thorne 2007
[2] Miller 1981; Sladky 1981; Latham 1993
[3] Barton and Wallenstein 1997; McCandless 1998
[4] Wherry 1963, 1970

In 1960 a Girl Scout troop "*put in some hard work cutting locusts and painting the stumps to prevent sprouting*."[1] The results were only temporary; in 1963 the *John J. Tyler Arboretum Bulletin* warned "*the work of curbing the trees must be picked up again*."[3] Little was done, however, and by 2000 the eastern half of the remaining grassland was turning into a black locust thicket. At around that time the Arboretum launched an eradication program that continues today, using spot-herbiciding. Nearly all of the black locusts in and near the grassland have been eliminated, with little or no apparently collateral damage to native species. However, seed sources still exist nearby and the program will have to be continued indefinitely throughout Pink Hill. There is still a stand of large black locusts in the woods near the eastern corner of Pink Hill next to the adjoining privately owned property. After the grassland is restored across most of the land it occupied in 1937, those trees will quickly invade it via rhizomes and propagate new trees by suckering unless they are eradicated.

Other nonnative invasive species in the remnant grassland have spread only along the grassland edges adjacent to forest, so far. The most serious offenders are ailanthus, Japanese honeysuckle, oriental bittersweet, multiflora rose, Japanese barberry, Japanese stiltgrass and Canada thistle (native to Eurasia, despite the misnomer). The most severely affected area is the northwestern margin of the existing grassland, along the forested slope near Dismal Run.

English ivy, periwinkle and sweet cherry are confined to the now-forested part of Pink Hill between the remnant grassland and Barren Road, mainly near the border with an adjoining privately owned property. A common nonnative invasive shrub that threatens the integrity of other serpentine barrens in the region, autumn-olive (*Elaeagnus umbellatus* Thunb.), was not found at Pink Hill in a 2008 survey but is likely to show up at some future time.

[1] Anonymous 1963, p. 4

Artificially elevated white-tailed deer population

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

Deer populations are no longer kept at ecologically sustainable levels as they were for more than 99% of their existence, first by large predators and later by Native Americans, for whom venison was a major source of food. A diverse array of predators regulated deer populations for millions of years before humans arrived in our region, including the timber wolf, dire wolf, grizzly bear, giant short-faced bear, mountain lion, American cheetah, and jaguar. Human hunters arrived in what is now southeastern Pennsylvania at least 13,000 years ago, forcing out most of the other major predators, but American Indians, timber wolves, and mountain lions continued to regulate deer populations until Europeans arrived and expelled all three. Recreational hunting as it is practiced today under strict game laws and for only a short interval in the fall has relatively little impact on deer population numbers.

Deer thrive best in the forest-edge habitat that timbering, farming and suburbanization have created over most of our region. The

unprecedented high numbers that exist in much of the region today consume the tree seedlings and saplings, shrubs and wildflowers that in more favorable circumstances make native forest and grassland ecosystems healthy, beneficial to wildlife and self-sustaining. Plant communities and plantings in the 125 acres inside the Tyler Arboretum's deer exclosure fence are recovering from decades of overbrowsing but Pink Hill lies outside the fence. Much of the forest on and surrounding Pink Hill has been stripped of understory vegetation. The dense layer of native shrubs, young trees, ferns and wildflowers that are the hallmark of a healthy forest is sparse or, in some parts, completely missing. The understory now is typically either largely devoid of plant life or choked with nonnative invasive species. Deer and other plant-eating wildlife generally avoid nonnative invasive plants, which is one of the reasons they can proliferate unchecked.

The effects of deer on the grassland is much more subtle. Many of the dominant plants are adapted to disturbance, including grazing and browsing. However, the species that are highly preferred by deer have little chance against the onslaught of the current deer population, which may be 20 times as high as it was through the ages. Plants known to be especially vulnerable include at least three current residents of Pink Hill that are probably no longer reproducing: Philadelphia wood lily, blackjack oak and bush oak (an unusual hybrid between blackjack oak and black oak that may be unique to Pink Hill among all of the remaining serpentine barrens). Deer eat the wood lily shoots before they can set seed and the oak seedlings before they can grow out of reach. The oaks may appear secure to the casual observer, but when the current adult trees die through natural decline, disease or windfall, the Pink Hill populations—perhaps many thousands of years old—will be gone forever. Several other vulnerable species have already been extirpated from Pink Hill, including colic-root, dwarf chestnut oak, post oak and spring ladies'-tresses. Deer may well have been a factor in the demise of others of the 92 species apparently extirpated from Pink Hill; likely candidates include wild indigo, Indian paintbrush and soapwort gentian.

Sustaining or restoring any of these species must start with the goal of reducing and maintaining deer density at an appropriate level. Unless this goal is achieved first, management of other stressors and any attempt at reintroduction will be a short-term lesson in futility that ultimately will end with the demise of the vulnerable species.

Philadelphia lily persists in small numbers even though it is a highly preferred deer food, but at Pink Hill no fruits survive to disperse viable seeds without protection from the unprecedented high deer numbers.

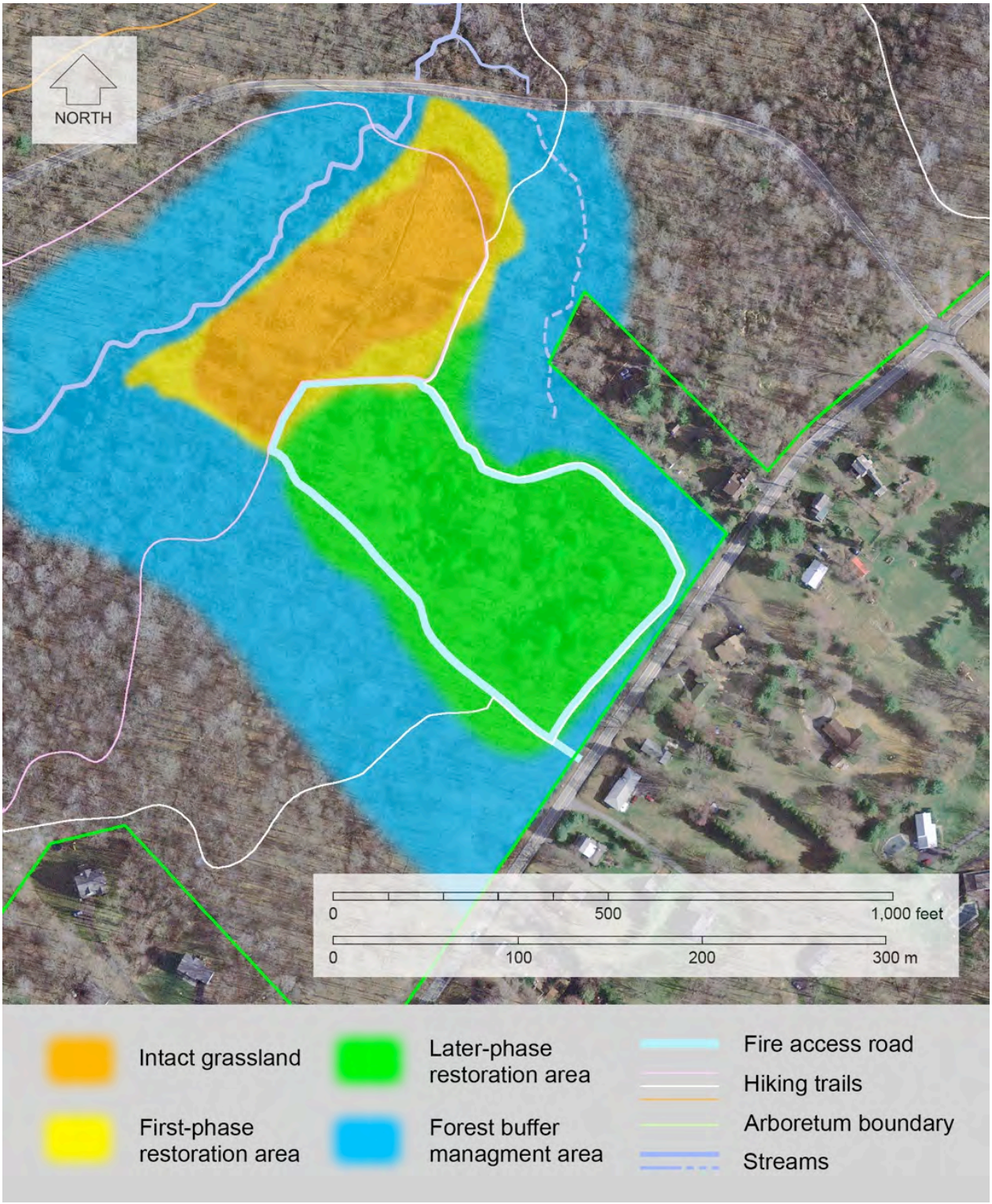


Figure 4. **Restoration and management zones at Pink Hill** overlain on 2005 aerial imagery[1] (Dismal Run is at upper left, Painter Road is at top, and Barren Road is at lower right). See descriptions of management priorities for each zone under *Restoration management tools and methods*.

[1] Delaware Valley Regional Planning Commission 2007

Restoration/management tools and methods

The key tools and methods for reducing or eliminating the principal threats identified in the previous section are:

1. **Prescribed burning**
2. **Invasive species control**
3. **Partial soil organic matter removal**
4. **Selective tree removal, site preparation and planting for grassland restoration**
5. **Baseline surveys focusing on rare plant and animal species**
6. **Species reintroduction and augmentation**
7. **Deer management or exclusion**
8. **Monitoring indicators of forward progress, setbacks, imminent problems and other trends**

Prescribed burning

Current best management practices for grassland in our region call for spring burning with 3–6 or more years between burns in a given area, depending on soil conditions. The higher the soil fertility, the more often burning is needed to sustain native grassland vegetation. On the thin soils of the remnant grassland (area in orange on the map in Figure 4), less frequent burns are needed. On the slightly thicker soils around its margins (area in yellow on the map) and still thicker soils of the wooded area to be restored to grassland (area in green), more frequent burns will be needed, once grassland vegetation is established, to achieve a similar effect. The frequency of burning required to maintain grassland in the restoration area may be as little as two years for two or three burn cycles at the beginning but it is expected to decrease with time as the grassland plants mature, especially in areas where the upper layer of soil organic matter is reduced by mechanical removal or to a lesser degree by repeated burning and natural erosion.

To sustain wildlife diversity, including grassland-restricted insect populations, it is crucial that the area burned in any one year be rotated among sections of the grassland landscape in different years. This will maintain refuges from which grassland-restricted insects and other wildlife can re-colonize the treated area. Only a fraction—no more than ¼–⅓—of the total grassland area may be burned in any year if the risk of extirpation is to be brought within acceptable limits. This dictum has not been followed at Pink Hill in past prescribed burns but reform on this issue will become increasingly important, as the size of the grassland is augmented by restoration to the point where it becomes progressively more likely to attract and sustain populations of rare insect species and other grassland-dependent wildlife.

The 2008 prescribed burn conducted in the remnant grassland by Natural Lands Trust's fire management team is a first-rate model for the establishment of a permanent fire management program at Pink Hill with the modification that the area treated in any one year needs to be scaled back to ¼–⅓ of the total grassland area. Routine burning will expand in its geographical scope to include each increment of additional grassland acreage added during restoration.

Invasive species control

The main invasive species problem spots are along the downslope edge of the remnant grassland (narrow yellow strip parallel to and just inside the site's northwestern border on the map in Figure 4) and in the woods along the east side of the site (wider, curved, blue strip from Painter Road to Barren Road on the map).

Information is readily available detailing methods for controlling invasive species in natural areas, summarizing the body of research and the successes and failures of practitioners on the ground. This literature

covers all of the major nonnative invasive plants at Pink Hill except sweet cherry, which can be eradicated simply by felling and flush-cutting stumps to ground level.

Best management practices for controlling invasive species on natural lands often call for application of herbicides such as glyphosate or triclopyr. Spot treatment using a wick-applicator or brush is to be preferred over broadcast application in every case in which spot treatment is likely to be effective. Broadcast application of herbicides in an ecosystem rich in rare plants such as a serpentine grassland unnecessarily risks serious damage to populations and to the ecosystem as a whole, which would violate the fundamental goals of conservation at Pink Hill.

On-line resources for invasive species management on natural lands:

- The Nature Conservancy's "Invasives 101: an Introduction to Invasive Species Management" (http://tncweeds.ucdavis.edu/methods.html) and element stewardship abstracts for particular species (http://tncweeds.ucdavis.edu/esadocs.html)
- Plant Conservation Alliance Alien Plant Working Group's "Weeds Gone Wild: Alien Plant Invaders of Natural Areas" (http://www.nps.gov/plants/alien).
- Pennsylvania Department of Conservation and Natural Resources' "Invasive Exotic Plant Management Tutorial for Natural Lands Managers" (http://www.dcnr.state.pa.us/forestry/invasivetutorial)

Publications on methods for controlling the major invasive species at Pink Hill[1]:

- **ailanthus**: Hoshovsky 1988; Swearingen and Pannill 2005
- **Japanese barberry**: Brunelle and Lapin 1996; Rhoads and Block 2002; Swearingen 2005
- **oriental bittersweet**: Dreyer 1994, Swearingen 2006
- **Canada thistle**: Nuzzo 1997a; Thunhorst and Swearingen 2005
- **English ivy**: Morisawa 1999; Swearingen and Diedrich 2006
- **Japanese honeysuckle**: Nuzzo 1997b; Bravo 2005
- **Amur honeysuckle**: Batcher and Stiles 2000; Williams 2005
- **Japanese stiltgrass**: Tu (undated); Swearingen and Sheherezade 2008
- **black locust**: Converse 1984; Wieseler 2005
- **multiflora rose**: Eckardt 1987; Bergmann and Swearingen 2005
- **periwinkle**: Bean and Russo 1988

In addition to a dozen nonnative invasive species, four native forest species have invaded the grassland at Pink Hill: red maple, sassafras, Virginia pine and common greenbrier. They are components of native diversity in this ecosystem that have probably been present since its origin and no attempt should be made to eradicate them; at any rate, they are so well established that any such attempt would be futile. However, the populations of red maple, sassafras and common greenbrier are large enough—likely due in part to fire exclusion in the mid-twentieth century—that special effort may be required in specific locations where they have begun to usurp space and lower diversity in the grassland. Virginia pine is too scarce to pose any problem at Pink Hill at present but it is has been a serious invader at other Pennsylvania serpentine barrens subjected to prolonged fire exclusion. It is placed in the "native invasive" category to encourage vigilance in case it should pose a risk at Pink Hill in the future.

[1] Full references for invasive species are listed together in their own subsection at the end of the References Cited section.

Red maple is best controlled by felling, cutting the stump flush with the ground, and painting the cut surface with a systemic herbicide such as triclopyr. Sassafras spreads through rhizomes, like black locust, but is apparently less tolerant of fire; routine prescribed burning for grassland maintenance should be enough to keep it from becoming a serious invader of the grassland. No chemical treatment is needed for Virginia pine, which, if it should ever need to be managed, is easily killed by fire or felling. Common greenbrier is best removed mechanically, a topic covered under *Partial soil organic removal*, below.

Partial soil organic matter removal

Mechanical removal and off-site disposal of the top few inches of organic-matter-rich soil beneath greenbrier thickets, including the vines' rhizomes and root systems, has been applied with outstanding success at several serpentine barrens site in Pennsylvania. The three areas treated in a 2002 pilot project at Pink Hill are now entirely dominated by plant species in the "highest-priority native species" list (category 4 in the Appendix). No planting or seeding was necessary; all plants seeded in naturally or came up from what remained of the seed bank and there are no invasive plants.

The pilot project had only two, very minor shortcomings, providing useful lessons to improve future performance. One is that a temporary stockpile of removed material was incompletely removed and has supported the growth of a small but dense patch of nonnative invasive species. The other is that a slightly deeper layer of organic matter was taken away than was necessary, resulting in sparse recolonization at two of the three treated areas. These sites will fill in gradually over the years and patchiness in the degree of mineral soil exposure and vegetation density is desirable in any case, so there was no damage done. However, operators conducting future removals should experiment with taking off soil organic matter to a range of depths and the vegetation responses should be carefully monitored (see *Monitoring indicators of forward progress, setbacks, imminent problems and other trends*, below), in order to refine the methods further.

The thick stands of Japanese stiltgrass, oriental bittersweet, multiflora rose and Japanese honeysuckle along the northwestern, downslope edge of remnant grassland is an opportune place to experiment with partial soil organic matter removal in a situation where the target invader is not greenbrier. This should be begun as a pilot project in multiple small areas at first and the vegetation response monitored for 2–3 years before the method is applied to the entire invaded area.

Partial soil organic matter removal will probably be an indispensible part of the restoration project within the fire road loop, at least in small areas where the growth of invasive species is now dense or becomes so after the tree canopy is removed. However, with the exception of a limited area near the boundary with the neighboring private property where English ivy, periwinkle, Japanese barberry and Japanese honeysuckle already form a dense cover, it should be delayed until at least two years after trees have been cut, grassland plants have established, and at least one prescribed burn has been conducted. By then, problem spots should be distinguishable from areas that can get along without this costly, labor-intensive treatment.

Selective tree removal, site preparation and planting for grassland restoration

The first step in restoring grassland to the area within the fire loop road (area in green on the map in Figure 4) is to cut down most of the trees. This can be done in phases or all at once. The mature oak-mixed hardwood forest should be strictly excluded—it is not a part of the area visible as grassland in the 1937 aerial photograph (the trunks of some northern red oaks in the east-central part of the site measure more than 4 feet in diameter). The restoration area is easily distinguished on the ground by the small size of nearly all trees, a large fraction of which are multi-stemmed.

Several tree species should be well marked and left undisturbed during cutting: blackjack oak, bush oak, scarlet oak and black oak. Cutters should not only leave them standing but also take care to protect their trunks against damage from machinery and falling trees. The trees to be removed are mainly red maple, sweet birch and sassafras, with scattered Virginia pine, American beech, northern red oak, white oak, black cherry, sweet cherry, gray birch, sweetgum, crabapple and white ash. All stumps should be ground or flush-cut level with the soil surface. Cut surfaces of root-sprouting species such as red maple and sassafras should be painted with a systemic herbicide.

Care should be taken to preserve intact a small patch of open woodland with a shrubby and grassy understory located just west of the center of the proposed restoration area. This contains a remnant stand of the uncommon shrub maleberry, growing together with lowbush blueberry, highbush blueberry, catbrier, silver-rod and poverty oatgrass. This patch is likely to remain a native shrubland after restoration of the surrounding grassland, contributing significantly to Pink Hill's natural diversity.

Consideration should be given to salvaging individuals of herbaceous species that are uncommon elsewhere in the Arboretum by transplanting them to the North Woods or other suitable habitat within the deer exclosure fence. One example is small whorled pogonia (*Isotria verticillata* (Muhl. ex Willd.) Raf.), a native orchid reported as living in the proposed restoration area[1].

Areas where trees are cut should be planted with a seed mixture of little bluestem, Indian-grass, and other native grasses and forbs collected from the remnant grassland. Seed may also be collected from remnant serpentine grasslands in Chester County, for instance, Sugartown Barrens (on Natural Lands Trust's Willisbrook Meadows Preserve), Brinton's Quarry (owned and managed by the Quarry Swimming Association), Fern Hill or Unionville Barrens (both privately owned but under consideration for protection by Natural Lands Trust, Brandywine Conservancy and West Chester University). *It is vitally important that seed from no other source be used.*

Seeding warm-season grasses and grass-forb mixtures into an area with rocky soils and flush-cut tree stumps will pose some major challenges, including but not limited to appropriate methods of seedbed preparation, the need for special equipment such as a warm-season grass seed drill, and proper seasonal timing. Advice on the most effective methods for the particular set of conditions at Pink Hill must be sought from experienced practitioners.

Several acres of forest contiguous to and just west of the site are marked in the county soil survey[2] as underlain by the same soil type (Chrome gravelly silty clay loam) as the remnant grassland and proposed restoration area. This area should be revisited in future iterations of this plan and consideration given to it as a potential expansion area for grassland restoration.

Baseline surveys focusing on rare plant and animal species

Before any species reintroductions are attempted, the first step is to undertake a thorough search, over at least one growing season, for characteristic serpentine grassland plant species that are thought to have been present historically at Pink Hill but have not been seen in recent years. It is possible that there are remnant populations so small as to have evaded observation. For instance, annual fimbry—a small sedge that is one of the few true desert annuals in our local flora—is visible only briefly following a rainy period within a relatively short time window during the growing season. In years when that period passes with little rainfall, few or no seeds germinate. Most of its life cycle is spent as

[1] Dick Cloud, personal communication (2000)

[2] Kunkle 1963

seeds, which can remain dormant (and invisible) in the soil seed bank for years. Many orchids also are cryptic for years at a time, living as underground root structures parasitic on soil fungi, and even when they do emerge aboveground, they often occur so sparsely that they may go unobserved.

A survey of invertebrate species, especially butterflies and moths, is needed to establish whether any of the rare species known to inhabit serpentine barrens in the region are present at Pink Hill. The Pennsylvania Natural Heritage Program (Western Pennsylvania Conservancy, Pittsburgh and Middletown) and the Carnegie Museum of Natural History's Section of Invertebrate Zoology (Pittsburgh) work together on similar surveys statewide and are best positioned and qualified to collect the data and interpret the results.

Species reintroduction and augmentation

Reintroducing species to Pink Hill that were once present there or in other, nearby barrens but are now gone mimics nature's island population "rescue effect" but on a shorter time-scale. Species selected for reintroduction may be planted as seeds or as greenhouse-reared plugs or potted plants. In all cases, only wild-collected seeds from one (or preferably more than one) of the nearest serpentine barrens sites in eastern and central Chester County are eligible to serve as reintroduction growing stock.

If there is a remnant population Pink Hill that has dwindled to such small size that it is in danger of being extirpated if not "rescued," it may benefit from augmentation. The 7–9-acre proposed restoration area is an ideal site for augmentation plantings; in a sense, all plantings there of species that now occur in the remnant grassland should properly be termed augmentation. The preferred first step is to use plugs or potted plants grown from seed collected from Pink Hill individuals. Long-term, if this stratagem should fail for any species, the next step would be using plugs or potted plants grown from seed collected from the nearest serpentine barrens where the species is still thriving.

Species proposed for reintroduction are ranked in six priority categories (Table 7 and Appendix). The highest priority group consists of 15 grassland species believed extirpated from Pink Hill that are either (1) officially listed species of special concern in Pennsylvania, (2) have high local fidelity to serpentine barrens, or (3) potentially are hosts for rare, grassland-dependent animal species. The other five groups, in descending order of priority, are: other grassland species extirpated from Pink Hill that are uncommon statewide; grassland species extirpated from now-destroyed local serpentine barrens that are officially listed species of special concern *and* have high local fidelity to serpentine barrens; grassland species extirpated from now-destroyed local serpentine barrens that are officially listed species of special concern only; grassland species extirpated from now-destroyed local serpentine barrens that have high local fidelity to serpentine barrens only; and other grassland species extirpated from now-destroyed local serpentine barrens that are uncommon statewide.

Deer management

Reducing and maintaining the local deer herd within an ecologically sustainable range of densities will be challenging, to put it mildly, and virtually impossible without close cooperation from neighboring landowners, municipal authorities, the Pennsylvania Game Commission, the superintendent and resource management staff of Ridley Creek State Park, and upper management at the district and Harrisburg offices of the Pennsylvania Department of Conservation and Natural Resources. The only methods currently in use that have proved effective in similar situations are (1) highly organized and intensively regulated yearly hunts by a select, trained group of recreational hunters, (2) annual culls by sharpshooters under contract, and (3) permanent exclusion of deer by fencing. Other approaches that are frequently

suggested in public discussions of deer management include trap-and-transfer and contraception; however, they are not practical or allowed by law at present except for short-term use in approved research projects.

In the regulated hunting option, participants are screened and required to pass a proficiency test so that only responsible and skilled hunters are allowed on site. The aim is to ensure quick, clean kills and maximize safety. Yearly training includes safety, ethics, rules of behavior and ecological issues. Participants must be persuaded that they are a vital part of the stewardship program and not simply involved in a recreational activity. Long-term, repeated participation is encouraged so that hunters' effectiveness is enhanced by familiarity with the land and the behavior of the local deer herd. Hunters sign an agreement that spells out violations of safe, honest and ethical behavior; anyone not acting accordingly has his or her permit revoked immediately. During hunts, maps locating hunter positions are distributed to participants and land managers. Hunters wear bright, identifying armbands that allow managers to tell from a distance if a person has permission to hunt. The rules emphasize removing females from the population, because it is almost exclusively the doe removal rate that influences population size. Preferentially harvesting does is capable of bringing populations to levels compatible with ecosystem health far more quickly than would a random removal strategy; preferentially harvesting bucks has almost no effect on birth rates and therefore is not capable of controlling deer population size.

For recreational hunting to be an effective strategy both the Tyler Arboretum and Ridley Creek State Park would need to participate in the Game Commission's deer management assistance program (DMAP). DMAP increases the number of deer hunting tags allocated on specific land units at the owners' request in order to keep deer populations in balance with their land-use goals, for instance, restoring ecosystem health and integrity. The Game Commission must approve a plan for each DMAP unit. Regulated hunting requires a considerable amount of staff time but the hunters' labor is free. Because of white-tailed deer's mobility across habitat areas of just a few square miles, the success of regulated hunting in the Tyler Arboretum depends critically on its implementation across an area much larger than the arboretum itself, including Ridley Creek State Park and other neighboring wooded areas and open fields.

The sharpshooter culling option does not involve recreational hunting. Qualified professional sharpshooters are hired each year to euthanize a fraction of the deer population within a unit of land. This requires a special permit from the Pennsylvania Game Commission, granted only if the landowner can make a convincing case that hunting within current game laws is not a viable option for managing the deer population at desired levels. Sharpshooter culling is the quietest (sharpshooters use rifle silencers) and probably the safest (removal is usually done at night using infrared sighting scopes, over isolated baiting stations located where shots are directed into the ground) method and is the most effective option for reducing the deer population in the shortest time. The venison is dressed and donated to charitable food banks or government-run institutions. Removal of other signs of the cull such as bloodied leaves may also be a part of the culling contractor's services. The cash outlay is relatively high but the time demands on the land manager can be considerably lower than that required to run a controlled hunting program. Culls must be performed annually, at least until ecosystem restoration is achieved. In some cases, once the deer population is reduced and overbrowsing impacts are alleviated, switching to a controlled hunting program may be adequate to maintain the desired deer population density. Like regulated hunting, sharpshooter culling is likely to succeed as an ecosystem restoration technique only if the owners and managers of neighboring forestlands and fields take similar action at the same time.

Deer-exclusion fencing, in contrast, does not require long-term cooperation by neighbors. Its up-front costs are considerable, but long-term costs—for monitoring and maintenance—are probably lower than for the other two options. To preserve aesthetics, minimize interference with fire management, and maintain flexibility for potential future expansion of the grassland restoration area, a fence excluding deer from Pink Hill would have to be located a considerable distance from the barrens edge, at a minimum, near or beyond the perimeter of the forest buffer management area (shown in blue in Figure 4).

Table 7. **Summary of plant species grouped by recommended management and restoration actions at Pink Hill** (summary of Appendix). The Appendix includes all vascular plants found in a 2008 survey of Pink Hill or recorded historically at Pink Hill and the cluster of now-destroyed serpentine grasslands within 2½ miles.

management/restoration action	spe-cies	category	criteria
Monitor and control	8	Nonnative invasive species	Nonnative invasive species surveyed in 2008 at Pink Hill that are impractical to eradicate but essential to keep to minimal population sizes
Eradicate	4	Nonnative invasive species	Nonnative invasive species surveyed in 2008 at Pink Hill that threaten native species and are practical to eradicate
Monitor and manage	4	Native invasive species	Native grassland invaders surveyed in 2008 at Pink Hill that are part of native diversity but require effort to keep from usurping space and lowering diversity
Monitor and maintain	27	Highest-priority native species present	Native grassland species surveyed in 2008 at Pink Hill that are officially listed species of special concern or have high local fidelity to serpentine barrens or potentially are hosts for rare animal species
Search (to confirm absence), reintroduce, monitor and maintain	15	Reintroduction priority 1	Native grassland species extirpated from Pink Hill that are officially listed species of special concern or have high local fidelity to serpentine barrens or potentially are hosts for rare animal species
Search (to confirm absence), reintroduce, monitor and maintain	10	Reintroduction priority 2	Native grassland species extirpated from Pink Hill that are uncommon statewide
Search (to confirm absence), reintroduce, monitor and maintain	8	Reintroduction priority 3	Native grassland species extirpated from now-destroyed local serpentine barrens that are officially listed species of special concern and that have high local fidelity to serpentine barrens
Search (to confirm absence), reintroduce, monitor and maintain	18	Reintroduction priority 4	Native grassland species extirpated from now-destroyed local serpentine barrens that are officially listed species of special concern (do not have high local fidelity to serpentine barrens)

(continued on next page)

management/restoration action	species	category	criteria
Consider reintroducing	11	Reintroduction priority 5	Native grassland species extirpated from now-destroyed local serpentine barrens that have high local fidelity to serpentine barrens (are not officially listed species of special concern)
Consider reintroducing	20	Reintroduction priority 6	Native grassland species extirpated from now-destroyed local serpentine barrens that are uncommon statewide
No action needed (except for incidental monitoring)	66	Miscellaneous native species	Native grassland or forest species surveyed in 2008 at Pink Hill
No action needed (except for incidental monitoring)	67	Miscellaneous native species	Native grassland or forest species apparently extirpated from Pink Hill
No action needed (except for incidental monitoring)	91	Miscellaneous native species	Native grassland or forest species documented historically at now-destroyed local serpentine barrens
Watch and, if necessary, control	19	Nonnative but noninvasive species	Nonnative species surveyed in 2008 at Pink Hill that are not considered likely to become invasive

Monitoring indicators of forward progress, setbacks, imminent problems and other trends

To be truly effective, a program of invasive plant management and grassland restoration must include a well-planned, efficient and rigorously executed monitoring program. Its purpose is to gauge the degree of success or failure of management measures by tracking trends in the populations of rare species and in the extent of rare plant communities over the long term. Monitoring will provide an early warning of any deterioration so action can be taken while the effort required for a successful remedy is still modest and practical. It will document the comparative successes of various measures employed for invasive plant management, providing the information necessary to determine what adjustments may be needed to maximize the efficiency and effectiveness of the management program.

Effective monitoring depends partly on choosing the right indicators. They need to reliably reflect the status of focal conservation targets and their responses to restoration and management treatments and they must be practical to measure given available personnel and resources. Indicators listed previously (under *Focal conservation targets and restoration/management objectives*) include:

- aggregate areas, measured from recent satellite photos, of savanna tree crowns and restored grassland
- species percent cover data collected on appropriately located, permanently marked transects and quadrats
- population rough counts of particular species of special interest based on observations from random walks over each species' entire habitat area
- estimates of fruit or seed production of particular species of special interest based on quantitative surveys of permanently marked transects and quadrats or rough counts from random walks over each species' entire habitat area

Effective monitoring also depends on placing enough sampling locations so that, in the aggregate, they are fully representative of the entire area covered by each conservation

target or management procedure. Transects (linear sampling areas) and quadrats (square, rectangular or circular sampling areas) should represent the full range of variability in approximately the same proportions as exists across the entire area covered by the conservation target. This is usually accomplished by (1) defining an area of interest (e.g., a series of greenbrier thickets to be treated by partial organic matter removal), (2) using a randomization procedure to choose potential sampling locations within that area (e.g., gridding the area on a map into an x,y-coordinate plane and using a random number table to pick coordinates for a series of 1-m^2 quadrats), and (3) establishing a set of acceptance and rejection criteria ahead of time so that any locations randomly picked that would not contribute useful information can be skipped over without bias (e.g., a 1-m^2 quadrat straddling a hiking trail).

In some cases, the area covered by the conservation target comes in two or more types on which different indicator states and responses are expected (e.g., some parts are on thin, dry soils and other parts are on deeper, moister soils). This calls for *stratifying* the monitoring locations, that is, establishing a set of criteria ahead of time so that all locations randomly picked can be assigned to one or the other type, or be rejected as being too close to the borderline between types to contribute useful information on the differences.

It is crucial to monitor some indicators in some locations every year because indicator status changes are expected to be significant at that time scale and accurate information on short-term trends is needed in order to prepare the following year's work plan. An example is percent cover of all species in areas subjected to grassland restoration treatment; another is estimated population size and fruit production of an endangered or threatened species with a dangerously low population or in the process of being reintroduced. Indicators that change more slowly can be monitored every second or third year, for instance, the percent cover of all species along transects through the remnant grassland, a population rough count of serpentine aster, the aggregate area of savanna tree crowns, and the total area of restored grassland.

Transects' ends and each quadrat's center or one corner are marked with a ½-inch steel rebar cut to 12-inch or 18-inch length and driven into the ground so that an inch or less is protruding, to minimize the risk of puncturing emergency or maintenance vehicles' tires. Optionally, a number-stamped aluminum tag may be securely attached to the end using wire, although the tags soften and deform and may even melt during prescribed burns. The locations of all markers should be recorded to the nearest 0.5 m using GPS.

If the data are not entered digitally in the field on an electronic data-recording device such as a Hammerhead™ pen computer, the same personnel who conduct the surveys should enter the data into computer spreadsheets during the survey period or as soon as possible thereafter, while memory of fieldwork is still fresh. Adhering to this rule minimizes errors and maximizes the chance that the errors that will inevitably occur are caught and corrected. The final, digital data files must also be proofread and meticulously crosschecked with the original notebooks or survey sheets. They should be stored as backups in more than one medium (e.g., DVD and hard disk drive) at multiple locations and perhaps be made available on-line.

Quantitative monitoring should be supplemented with photographs taken annually at fixed photo points. It is efficient to use some of the permanently marked transect and quadrat markers for most of the photo points, adding markers where needed at other appropriate locations. Digital images should be labeled with locations and dates using photo-cataloging software, stored with an up-to-date version of the catalog in at least two media at multiple locations, and perhaps be made available on-line.

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Appendix: Vascular Plants Now Present or Recorded Historically at Pink Hill and the Former Local Cluster of Serpentine Grasslands

The list is based on a recent survey[1] and herbarium records[2]. The 368 vascular plant taxa (species, subspecies, varieties) are arranged in 14 numbered categories, based on recommended restoration or management actions (see Table 3 for explanation of categories and Table A for a breakdown of the 368 taxa by other groupings). The codes used in the data columns are:

Pink Hill grassland 2008 Pink Hill edge/woods 2008	Estimated abundance (numbers or percent surface cover) in grassland or in woods or woods edges based on 2008 survey[1]:			
	1	sparse	**c**	clumped (distribution is highly localized)
	2	low intermediate		
	3	high intermediate	*	I.D. based on non-flowering specimen, needs further verification
	4	abundant		
wetland status[2]	**OBL**	obligate wetland species		
	FACW	mainly wet or mesic habitats	+	wetter
	FAC	mainly mesic habitats	–	drier
	FACU	mainly mesic or upland habitats		
	UPL	mainly upland habitats		
C_3/C_4 (grasses only)[2]	**C_3**	cool-season grass species		
	C_4	warm-season grass species		
growth form[2]	**HA**	herbaceous annual	**TD**	deciduous tree
	HB	herbaceous biennial	**TE**	evergreen tree
	HP	herbaceous perennial	**VA**	annual herbaceous vine
	SD	deciduous shrub	**VP**	perennial herbaceous vine
	SE	evergreen shrub	**VW**	woody vine
habitat preference[2]	**G**	lives mainly in grasslands and meadows		
	W	lives mainly in woodlands and forests		
	G/W	lives in either grasslands or open woodlands		
state status[2]	**PE**	endangered	**PX**	extirpated
	PR	rare	**TU**	status tentatively undetermined and under study
	PT	threatened		
serpentine fidelity[3]	**1**	regionally restricted or nearly restricted to serpentine barrens		
	2	regionally much more frequent on serpentine barrens than in other habitats		
historical at Pink Hill[2]	**x**	documented to have occurred historically at Pink Hill		
historical at 8 serpentine sites[2]		number of sites where species is documented to have occurred out of the eight serpentine grasslands that existed historically within 2½ miles of Pink Hill		

[1] Conducted throughout the 2008 growing season by Roger Latham
[2] Pennsylvania Flora Project database, Morris Arboretum of the University of Pennsylvania, courtesy of Tim Block and Ann Rhoads
[3] Pennell 1910, 1912

Table A1. **Numbers of vascular plant species on the list within various categories**

Native species surveyed in 2008 at Pink Hill	97
Nonnative species surveyed in 2008 at Pink Hill	31
Total species surveyed in 2008 at Pink Hill	128
Native grassland species documented historically at Pink Hill but not found in 2008	92
Other native grassland species documented historically at now-destroyed local serpentine barrens	148
Total native grassland species on list documented historically but not found in 2008 at Pink Hill	240
Grand total	369
Other breakdowns:	
Nonnative invasive species that require management now	12
Highest-priority native species present	27
Reintroduction priority 1	15
Reintroduction priority 2	10
Reintroduction priority 3	8
Reintroduction priority 4	18
Reintroduction priority 5	11
Reintroduction priority 6	20
Native species—present or extirpated—for which no action is needed	225

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
1	**MONITOR AND CONTROL NONNATIVE INVASIVE SPECIES. Criteria: nonnative invasive species surveyed in 2008 at Pink Hill that are impractical to eradicate but essential to keep to minimal population sizes**											
1	*Berberis thunbergii* DC	Japanese barberry		2 c			SD	G/W				
1	*Celastrus orbiculatus* Thunb.	Oriental bittersweet	2 c	2 c			VW	G/W				
1	*Cirsium arvense* (L.) Scop.	Canada thistle	1				HP	G				
1	*Lonicera japonica* Thunb.	Japanese honeysuckle		3 c	FAC–		VW	G/W			x	1
1	*Lonicera maackii* (Rupr.) Maxim.	Amur honeysuckle		2 c			SD	G/W				
1	*Microstegium vimineum* (Trin.) A.Camus.	Japanese stiltgrass	3 c	3 c	FAC	C_4	HA	G/W				
1	*Robinia pseudoacacia* L.	black locust		2 c	FACU–		TD	G/W			x	1
1	*Rosa multiflora* Thunb. ex Murray	multiflora rose		3 c			SD	G/W				
2	**ERADICATE NONNATIVE INVASIVE SPECIES. Criteria: nonnative invasive species surveyed in 2008 at Pink Hill that are important and practical to eradicate**											
2	*Ailanthus altissima* (P.Mill.) Swingle	ailanthus, tree-of-heaven		1 c			TD	G/W				1
2	*Hedera helix* L.	English ivy		1 c			VW	W				
2	*Prunus avium* (L.) L.	sweet cherry, bird cherry		1			TD	W				1
2	*Vinca minor* L.	periwinkle, creeping-myrtle		2 c			HP	W				
3	**MONITOR AND MANAGE NATIVE INVASIVE SPECIES. Criteria: native grassland invaders surveyed in 2008 at Pink Hill that are part of native diversity but require effort to keep from usurping space and lowering diversity**											
3	*Acer rubrum* L.	red maple		4	FAC		TD	W			x	4
3	*Pinus virginiana* P.Mill.	Virginia pine		1 c			TE	G/W		2		

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
3	*Sassafras albidum* (Nutt.) Nees	sassafras	2	3	FACU–		TD	G/W				4
3	*Smilax rotundifolia* L.	common greenbrier, bullbrier, round-leaved greenbrier	4	3 c	FAC		VW	G/W		2		3
4	**MONITOR AND MAINTAIN HIGHEST-PRIORITY NATIVE SPECIES. Criteria: native grassland species surveyed in 2008 at Pink Hill that are officially listed species of special concern or have high local fidelity to serpentine barrens or potentially are hosts for rare animal species**											
4	*Arabis lyrata* L.	lyre-leaved rockcress	2		FACU		HB HP	G		2	x	5
4	*Aristida longespica* Poir. var. *longespica*	slender three-awn, slimspike three-awn	2 c		UPL	C_4	HA	G		2	x	4
4	*Aristida purpurascens* Poir.	arrow-feather three-awn	2 c			C_4	HP	G	PT	2	x	5
4	*Carex glaucodea* Tuck.	blue sedge	1	1			HP	G/W		2		2
4	*Ceanothus americanus* L.	New Jersey tea	2				SD	G/W			x	7
4	*Cerastium velutinum* L. var. *velutinum*	barrens chickweed	3				HP	G		1	x	6
4	*Dichanthelium acuminatum* (Sw.) Gould and C.A.Clark	tapered rosette grass	2		FAC	C_3	HP	G/W		2		3
4	*Dichanthelium oligosanthes* (Schult.) Gould	Heller's witchgrass, Scribner's panic grass	3		FACU	C_3	HP	G	TU	2		7
4	*Dichanthelium sphaerocarpon* (Elliott) Gould	round-fruited panic grass, round-seeded panic grass	2		FACU	C_3	HP	G/W		2	x	8

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
4	*Eragrostis spectabilis* (Pursh) Steud.	purple lovegrass, tumblegrass	1 c		UPL	C_4	HP	G				1
4	*Houstonia caerulea* L.	bluets, Quaker-ladies	2 c		FACU		HP	G			x	3
4	*Juncus secundus* P.Beauv. ex Poir.	lopsided rush	1		FACU		HP	G		2	x	5
4	*Lilium philadelphicum* L.	wood lily	1		FACU+		HP	G/W		2	x	3
4	*Lobelia spicata* Lam. var. *spicata*	spiked lobelia	1		FAC–		HP	G				3
4	*Lyonia ligustrina* (L.) DC	maleberry, stagger-bush		1 c	FACW		SD	W			x	2
4	*Muhlenbergia mexicana* (L.) Trin.	Mexican muhly, satingrass	2 c		FACW	C_4	HP	G/W		2	x	2
4	*Packera anonyma* (A.W.Wood) W.A.Weber & A.Love	Appalachian groundsel, plain ragwort	2		UPL		HP	G	PR	2		4
4	*Phlox subulata* L. ssp. *subulata*	moss phlox, moss-pink, creeping phlox	3				HP	G		1	x	6
4	*Polygonum tenue* Michx.	slender knotweed	1 c				HA	G		2	x	7
4	*Quercus marilandica* Muenchh.	blackjack oak	2				TD	G/W		1	x	3
4	*Quercus marilandica* x *velutina*	bush oak		1 c			TD	G/W			x	1
4	*Sabatia angularis* (L.) Pursh	common marsh-pink, rose-pink	1		FAC+		HA	G/W		2	x	4
4	*Saxifraga virginiensis* Michx.	early saxifrage	1 c		FAC–		HP	G			x	1

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
4	*Schizachyrium scoparium* (Michx.) Nash var. *scoparium*	little bluestem	4		FACU	C_4	HP	G/W			x	6
4	*Sorghastrum nutans* (L.) Nash	Indian-grass	4		UPL	C_4	HP	G				5
4	*Symphyotrichum depauperatum* (Fernald) Nesom	serpentine aster	3				HP	G	PT	1	x	2
4	*Viola sagittata* Aiton var. *sagittata*	arrow-leaved violet	3 c		FACW		HP	G/W		2	x	6
5	**SEARCH, REINTRODUCE, MONITOR AND MAINTAIN (REINTRODUCTION PRIORITY 1). Criteria: native grassland species extirpated from Pink Hill that are officially listed species of special concern or have high local fidelity to serpentine barrens or potentially are hosts for rare animal species**											
5	*Aletris farinosa* L.	colic-root			FAC		HP	G/W	PE		x	1
5	*Asclepias verticillata* L.	whorled milkweed					HP	G		1	x	8
5	*Baptisia tinctoria* (L.) Vent.	wild indigo					HP	G/W			x	4
5	*Castilleja coccinea* (L.) Spreng.	Indian paintbrush			FAC		HA	G	PT		x	6
5	*Dichanthelium annulum* (Ashe) LeBlond	annulus panic grass				C_3	HP	G	PT		x	8
5	*Fimbristylis annua* (All.) Roem. & Schult.	annual fimbry			FACW–		HA	G	PT	1	x	4
5	*Gentiana saponaria* L.	soapwort gentian			FACW		HP	G/W	PE		x	1
5	*Lespedeza capitata* Michx.	round-headed bush-clover, round-headed lespedeza			FACU–		HP	G/W		2	x	5
5	*Minuartia michauxii* (Fernald) Farw.	rock sandwort					HA HP	G		1	x	1

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
5	*Panicum philadelphicum* Bernh. ex Trin.	Philadelphia panic grass			FAC–	C_4	HA	G/W		2	x	1
5	*Quercus prinoides* Willd.	dwarf chestnut oak					SD	G/W		2	x	6
5	*Quercus stellata* Wangenh.	post oak			UPL		TD	G/W		2	x	6
5	*Scutellaria serrata* Andr.	showy skullcap					HP	G/W	PE		x	1
5	*Sphenopholis obtusata* (Michx.) Scribn. var. *obtusata*	prairie wedgegrass			FAC–	C_3	HP	G		2	x	3
5	*Spiranthes vernalis* Engelm. & A.Gray	spring ladies'-tresses			FAC		HP	G	PE		x	2
6	**SEARCH, REINTRODUCE, MONITOR AND MAINTAIN (REINTRODUCTION PRIORITY 2). Criteria: native grassland species extirpated from Pink Hill that are uncommon statewide**											
6	*Antennaria parlinii* Fernald	Parlin's pussytoe					HP	G/W			x	1
6	*Carex conoidea* Willd.	open-field sedge			FACU		HP	G			x	2
6	*Carex umbellata* Willd.	parasol sedge					HP	G/W			x	1
6	*Chamaelirium luteum* (L.) A.Gray	devil's-bit, fairy-wand			FAC		HP	G/W			x	4
6	*Cirsium muticum* Michx.	swamp thistle			OBL		HB	G			x	3
6	*Geranium carolinianum* L.	Carolina cranesbill, Carolina geranium					HA	G/W			x	1
6	*Helianthus strumosus* L.	rough-leaved sunflower					HP	G/W			x	1
6	*Ophioglossum pusillum* Raf.	northern adder's-tongue					HP	G/W			x	2
6	*Silene stellata* (L.) W.T.Aiton	starry campion					HP	G/W			x	2

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
7	**REINTRODUCE, MONITOR AND MAINTAIN (REINTRODUCTION PRIORITY 3). Criteria: native grassland species extirpated from now-destroyed local serpentine barrens that are officially listed species of special concern and that have high local fidelity to serpentine barrens**											
7	*Ageratina aromatica* (L.) Spach	small-leaved white-snakeroot					HP	G/W	PR	2		5
7	*Carex bicknellii* Britton	Bicknell's sedge					HP	G/W	PE	1		4
7	*Deschampsia cespitosa* (L.) P.Beauv.	tufted hairgrass			FACW	C_3	HP	G	TU	1		2
7	*Helianthemum bicknellii* Fernald	Bicknell's hoary rockrose					HP	G/W	PE	2		3
7	*Juncus dichotomus* Elliott	forked rush			FACW–		HP	G/W	PE	2		1
7	*Prenanthes serpentaria* Pursh	lion's-foot					HP	G/W	TU	2		2
7	*Scleria pauciflora* Muhl ex Willd.	few-flowered nut-rush			FACU+		HP	G/W	PT	1		4
7	*Scleria triglomerata* Michx.	whip-grass, nut-rush			FAC		HP	G	TU	2		1
8	**REINTRODUCE, MONITOR AND MAINTAIN (REINTRODUCTION PRIORITY 4). Criteria: native grassland species extirpated from now-destroyed local serpentine barrens that are officially listed species of special concern**											
8	*Andropogon gyrans* Ashe	Elliott's beardgrass				C_4	HP	G/W	PR			1
8	*Buchnera americana* L.	bluehearts			FACU		HB	G	PX			3
8	*Cirsium horridulum* Michx.	yellow thistle, horrible thistle			FACU–		HB	G	PE			2
8	*Desmodium glabellum* (Michx.) Kuntze	tall tick-trefoil					HP	G/W	TU			3
8	*Desmodium nuttallii* (Schindl.) Schub.	Nuttall's tick-trefoil					HP	G/W	TU			1
8	*Desmodium obtusum* (Muhl. ex Willd.) DC.	stiff tick-trefoil					HP	G/W	TU			3

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
8	*Dichanthelium villosissimum* (Nash) Freckmann	long-haired panic grass				C_3	HP	G/W	TU			1
8	*Dichanthelium yadkinense* (Ashe) Mohlenbr.	Yadkin River panic grass				C_3	HP	G/W	TU			1
8	*Gentiana villosa* L.	striped gentian					HP	G/W	PE			1
8	*Linum intercursum* E.P.Bicknell	sandplain wild flax					HP	G	PE			1
8	*Paspalum setaceum* Michx. var. *muhlenbergii* (Nash) D.J.Banks	slender beadgrass, hairy beadgrass			FACU+	C_4	HP	G	TU			2
8	*Phlox pilosa* L.	downy phlox, prairie phlox			FACU		HP	G/W	PE			2
8	*Rosa virginiana* P.Mill.	Virginia wild rose			FAC		SD	G/W	TU			2
8	*Smallanthus uvedalia* (L.) Mack. ex Small	bear's-foot, leaf-cup					HP	G	PT			1
8	*Spiranthes tuberosa* Raf.	slender ladies'-tresses			FACU–		HP	G/W	PX			1
8	*Stylosanthes biflora* (L.) Britton, Stearns & Poggenb.	pencil-flower					HP	G	PE			4
8	*Symphyotrichum ericoides* (L.) Nesom ssp. *ericoides*	white heath aster			FACU		HP	G	TU			5
8	*Vernonia glauca* (L.) Willd.	Appalachian ironweed, tawny ironweed					HP	G	PE			2

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
9	**CONSIDER REINTRODUCING (REINTRODUCTION PRIORITY 5). Criteria: native grassland species extirpated from now-destroyed local serpentine barrens that have high local fidelity to serpentine barrens**											
9	*Agrostis hyemalis* (Walter) Britton, Stearns & Poggenb.	fly-away grass, ticklegrass			FAC	C_3	HP	G		2		2
9	*Angelica venenosa* (Greenway) Fernald	deadly angelica, hairy angelica					HP	G/W		2		3
9	*Asclepias viridiflora* Raf.	green milkweed					HP	G/W		2		4
9	*Carex retroflexa* Schkuhr	reflexed sedge					HP	G/W		2		4
9	*Comandra umbellata* (L.) Nutt.	bastard toadflax			FACU–		HP	G/W		2		2
9	*Heliopsis helianthoides* (L.) Sweet	ox-eye, smooth ox-eye					HP	G/W		2		2
9	*Lespedeza virginica* (L.) Britton	slender bush-clover, slender lespedeza					HP	G		2		5
9	*Quercus ilicifolia* Wangenh.	scrub oak, bear oak					SD	G		2		2
9	*Sanguisorba canadensis* L.	American burnet			FACW+		HP	G		2		2
9	*Sisyrinchium mucronatum* Michx.	needletip blue-eyed-grass			FAC+		HP	G		2		2
9	*Spiraea latifolia* (Aiton) Borkh.	meadow-sweet			FAC+		SD	G		2		1
10	**CONSIDER REINTRODUCING (REINTRODUCTION PRIORITY 6). Criteria: native grassland species extirpated from now-destroyed local serpentine barrens that are uncommon statewide**											
10	*Agastache scrophulariifolia* (Willd.) Kuntze	purple giant-hyssop					HP	G/W				1
10	*Asclepias purpurascens* L.	purple milkweed			FACU		HP	G/W				3
10	*Chamaecrista fasciculata* (Michx.) Greene	partridge-pea, prairie senna			FACU		HA	G				1

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10	*Desmodium marilandicum* (L.) DC	Maryland tick-clover					HP	G/W				4
10	*Dichanthelium boscii* (Poir.) Gould and C.A.Clark	Bosc's panic grass				C_3	HP	G/W				2
10	*Dichanthelium depauperatum* (Muhl.) Gould	poverty panic grass				C_3	HP	G/W				2
10	*Digitaria filiformis* (L.) Koeler	slender crabgrass				C_4	HA	G				1
10	*Diodia teres* Walter	rough buttonweed					HA	G				1
10	*Doellingeria infirma* (Michx.) E.Greene	flat-topped white aster					HP	G/W				1
10	*Eleocharis tenuis* (Willd.) var. *pseudoptera* Schult. (Weatherby) Svenson	slender spike-rush			FACW+		HP	G				1
10	*Galium pilosum* Aiton	hairy bedstraw, cleavers					HP	G				3
10	*Lechea pulchella* Raf.	Leggett's pinweed					HP	G/W				3
10	*Lespedeza hirta* x *intermedia*	Nuttall's bush-clover					HP	G/W				2
10	*Lespedeza repens* (L.) W.Bartram	creeping bush-clover					HP	G/W				3
10	*Liatris spicata* (L.) Willd. var. *spicata*	dense blazing-star			FAC+		HP	G				1
10	*Paspalum laeve* Michx.	field beadgrass			FAC+	C_4	HP	G				2
10	*Setaria parviflora* (Poir.) Kerguelen	perennial foxtail			FAC	C_4	HP	G				1

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10	*Tephrosia virginiana* (L.) Pers.	goat's-rue					HP	G/W				1
10	*Veronicastrum virginicum* (L.) Farw.	Culver's-root			FACU		HP	G				2
10	*Vulpia octoflora* (Walter) Rydb. var. *glauca* (Nutt.) Fernald	six-weeks fescue			UPL	C_3	HA	G				1
11	**NO ACTION NEEDED (EXCEPT INCIDENTAL MONITORING) FOR MISCELLANEOUS NATIVE SPECIES. Criteria: native grassland or forest species surveyed in 2008 at Pink Hill**											
11	*Ageratina altissima* (L.) R.M.King & H.Robinson var. *altissima*	common white snakeroot	1				HP	G/W				
11	*Agrostis perennans* (Walter) Tuck.	autumn bentgrass, upland bentgrass	2		FACU	C_3	HP	G			x	3
11	*Agrostis scabra* Willd.	fly-away grass, ticklegrass		1	FAC	C_3	HP	G/W				
11	*Ambrosia artemisiifolia* L.	common ragweed	2	1 c	FACU		HA	G				1
11	*Antennaria plantaginifolia* (L.) Hook.	plantain-leaved pussytoe	2 c				HP	G/W			x	3
11	*Aristida dichotoma* Michx. var. A.Gray var. *dichotoma*	poverty three-awn, churchmouse three-awn	2 c		UPL	C_4	HA	G			x	6
11	*Betula lenta* L.	black birch, sweet birch		3			TD	G/W				
11	*Betula populifolia* Marshall	gray birch		1 c			TD	G/W				
11	*Carex pensylvanica* Lam.	Pennsylvania sedge	2*	2*			HP	G/W				
11	*Carex platyphylla* Carey	broad-leaf sedge		1 c			HP	G/W				
11	*Carya tomentosa* (Poir.) Nutt.	mockernut hickory		1 c	FACU		TD	G/W				

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11	*Chimaphila umbellata* (L.) W.P.C.Barton	pipsissewa, prince's-pine		1 c			HP	G/W				
11	*Danthonia spicata* (L.) P.Beauv. ex Roem. & Schult.	poverty grass, poverty oatgrass	1	1		C_3	HP	G/W				1
11	*Dennstaedtia punctilobula* (Michx.) T.Moore	hay-scented fern	2	3			HP	G/W				1
11	*Dichanthelium clandestinum* (L.) Gould	deer-tongue, deer-tongue grass	1	2	FAC+	C_3	HP	G/W			x	2
11	*Erechtites hieraciifolius* (L.) Raf. ex DC	fireweed, pilewort	1	1 c	FACU		HA	G				1
11	*Euthamia graminifolia* (L.) Nutt.	grass-leaved goldenrod, flat-topped goldenrod	2		FAC		HP	G			x	3
11	*Eutrochium fistulosum* (Barratt) E.E.Lamont	joe-pye-weed, hollow-stemmed joe-pye-weed, trumpetweed		1 c	FACW		HP	G			x	1
11	*Fagus grandifolia* Ehrh.	American beech		2			TD	W			x	2
11	*Fraxinus americana* L. var. *americana*	white ash		3			TD	G/W				
11	*Hypericum punctatum* Lam.	spotted St. John's-wort	1		FAC–		HP	G				2
11	*Ilex opaca* Aiton	American holly		1			TE	W				
11	*Juglans cinerea* L.	butternut		1 c			TD	W				
11	*Juncus tenuis* Willd. var. *tenuis*	path rush	1 c		FAC–		HP	G/W				2
11	*Juniperus virginiana* L.	eastern red-cedar		1 c	FACU		TE	G			x	1
11	*Leersia virginica* Willd.	cutgrass, whitegrass	2 c	3	FACW	C_3	HP	G/W			x	4

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11	*Lindera benzoin* (L.) Blume	spicebush		2			SD	W				
11	*Liquidambar styraciflua* L.	sweetgum		1 c			TD	W				1
11	*Liriodendron tulipifera* L.	tuliptree, yellow-poplar		2			TD	W				
11	*Nyssa sylvatica* Marshall	sourgum, blackgum, tupelo		2	FAC		TD	W				2
11	*Oenothera perennis* L.	small sundrops, little evening-primrose	1				HP	G				
11	*Onoclea sensibilis* L.	sensitive fern		1 c	FACW		HP	G/W				1
11	*Parthenocissus quinquefolia* (L.) Planch.	Virginia-creeper, woodbine		3			VW	G/W				
11	*Persicaria pensylvanica* (L.) M.Gomez	Pennsylvania smart-weed, pinkweed	1		FACW		HA	G/W				1
11	*Pinus strobus* L.	eastern white pine		1 c			TE	W				
11	*Polystichum acrostichoides* (Michx.) Schott	Christmas fern	1 c	1			HP	G/W			x	1
11	*Populus grandidentata* Michx.	bigtooth aspen		1	FACU–		TD	W			x	2
11	*Potentilla canadensis* L.	dwarf cinquefoil	2				HP	G/W				4
11	*Potentilla simplex* Michx.	old-field cinquefoil		3	FACU–		HP	G/W			x	1
11	*Prunus serotina* Ehrh.	wild black cherry		2	FACU		TD	W				
11	*Pycnanthemum tenuifolium* Schrad.	narrow-leaved mountain-mint, slender mountain-mint	4		FACW		HP	G/W			x	7
11	*Quercus alba* L.	white oak		2			TD	W			x	3
11	*Quercus coccinea* Muenchh.	scarlet oak		3			TD	W			x	3

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11	*Quercus rubra* L.	northern red oak		2	FACU–		TD	W				3
11	*Quercus velutina* Lam.	black oak		2			TD	W				2
11	*Rhododendron periclymenoides* (Michx.) Shinners	pinxter-flower		1 c*	FAC		SD	W				2
11	*Rubus allegheniensis* Porter	common blackberry	2*	2*	FACU–		SD	G/W				
11	*Rubus flagellaris* Willd.	prickly dewberry, northern dewberry	1*	2*	FACU		VW	G				4
11	*Rubus occidentalis* L.	black-cap, black raspberry		1 c			SD	G/W				1
11	*Rubus pensilvanicus* Poir.	blackberry		2*			SD	G/W				2
11	*Smilax glauca* Walter	catbrier, cat greenbrier	2	2	FACU		VW	G/W		2	x	5
11	*Solidago altissima* L.	late goldenrod	1		FACU		HP	G/W				1
11	*Solidago bicolor* L.	silver-rod, white goldenrod	2	2			HP	G/W			x	5
11	*Solidago nemoralis* Aiton	gray goldenrod					HP	G/W			x	7
11	*Solidago rugosa* P.Mill. ssp. *rugosa* var. *rugosa*	wrinkle-leaf goldenrod	4	1 c	FAC		HP	G/W			x	5
11	*Symphyotrichum lateriflorum* (L.) A.Love & D.Love	calico aster	1	1	FACW–		HP	G/W			x	6
11	*Symphyotrichum undulatum* (L.) Nesom	clasping heart-leaved aster	2				HP	G/W			x	5
11	*Thelypteris noveboracensis* (L.) Nieuwl.	New York fern	1 c				HP	G/W				
11	*Toxicodendron radicans* (L.) Kuntze	poison-ivy		2			VW	G/W				

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11	*Tridens flavus* (L.) A.Hitchc.	purpletop	2		FACU	C_4	HP	G				3
11	*Vaccinium angustifolium* Aiton	low sweet blueberry		1 c*	FACU–		SD	G/W				2
11	*Vaccinium corymbosum* L.	highbush blueberry		1	FACW–		SD	G/W				2
11	*Vaccinium pallidum* Aiton	lowbush blueberry	4 c	4			SD	G/W			x	4
11	*Vaccinium stamineum* L.	deerberry		1	FACU–		SD	G/W			x	4
11	*Viburnum dentatum* L.	southern arrow-wood		1			SD	W				2
11	*Vitis aestivalis* Michx.	summer grape, pigeon grape		2 c	FACU		VW	W			x	4
12	**NO ACTION NEEDED (EXCEPT INCIDENTAL MONITORING) FOR MISCELLANEOUS NATIVE SPECIES. Criteria: native grassland or forest species apparently extirpated from Pink Hill**											
12	*Acalypha rhomboidea* Raf.	common three-seeded mercury			FACU–		HA	G/W			x	2
12	*Antennaria neglecta* Greene	overlooked pussytoe			UPL		HP	G			x	2
12	*Asclepias tuberosa* L.	butterfly-weed					HP	G/W			x	2
12	*Botrychium dissectum* Spreng.	cut-leaved grape-fern			FAC		HP	G/W			x	3
12	*Carex amphibola* Steud.	eastern narrow-leaved sedge			FAC		HP	G/W			x	1
12	*Carex atlantica* Bailey ssp. *atlantica*	bog sedge			FACW+		HP	G/W			x	2
12	*Carex gracilescens* Steud.	slender loose-flower sedge					HP	G/W			x	1
12	*Carex scoparia* Schkuhr ex Willd.	broom sedge			FACW		HP	G			x	3

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12	*Cirsium pumilum* (Nutt.) Spreng.	pasture thistle					HB	G/W			x	2
12	*Comptonia peregrina* (L.) J.M.Coult.	sweet-fern					SD	G/W			x	3
12	*Corylus americana* Walter	American filbert, hazelnut			FACU–		SD	G/W			x	3
12	*Cyperus echinatus* (L.) A.Wood	globe flatsedge, umbrella sedge			FACU		HP	G/W			x	1
12	*Cyperus lupulinus* (Sprengel) Marcks	Great Plains flatsedge, sand sedge			UPL		HP	G/W			x	4
12	*Cyperus strigosus* L.	false nutsedge			FACW		HP	G/W			x	3
12	*Dichanthelium dichotomum* (L.) Gould	cypress panic grass			FAC	C_3	HP	G/W			x	5
12	*Eragrostis pectinacea* (Michx.) Nees	Carolina lovegrass			FAC	C_4	HA	G			x	6
12	*Erigeron pulchellus* Michx.	robin's-plantain			FACU		HB HP	G/W			x	1
12	*Eupatorium perfoliatum* L.	common boneset			FACW+		HP	G			x	3
12	*Euphorbia corollata* L.	flowering spurge					HP	G/W			x	4
12	*Fragaria virginiana* Duchesne	wild strawberry			FACU		HP	G/W			x	1
12	*Galium aparine* L.	stickywilly, bedstraw, cleavers, goosegrass			FACU		HA	G/W			x	2
12	*Gaylussacia baccata* (Wangenh) K.Koch	black huckleberry			FACU		SD	G/W			x	4
12	*Helenium autumnale* L.	common sneezeweed			FACW+		HP	G			x	2

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12	*Helianthus giganteus* L.	swamp sunflower			FACW		HP	G			x	3
12	*Hieracium gronovii* L.	hawkweed			UPL		HP	G/W			x	4
12	*Hieracium venosum* L.	rattlesnake-weed					HP	G/W			x	3
12	*Hypoxis hirsuta* (L.) Coville	yellow star-grass			FAC		HP	G/W			x	2
12	*Juncus marginatus* Rostk.	grass-leaved rush			FACW		HP	G			x	2
12	*Lilium canadense* L. ssp. *canadense*	Canada lily			FAC+		HP	G/W			x	1
12	*Linum medium* (Planch.) Britton var. *texanum* (Planch.) Fernald	yellow flax			FACU		HP	G			x	2
12	*Liparis loeselii* (L.) L.Rich.	yellow twayblade			FACW		HP	G/W			x	2
12	*Luzula echinata* (Small) F.J.Herm.	common woodrush			FACU		HP	G/W			x	4
12	*Maianthemum racemosum* (L.) Link..	Solomon's-plume, false Solomon's-seal					HP	W			x	2
12	*Malus coronaria* (L.) Mill.	sweet crabapple					TD	G/W			x	1
12	*Mitchella repens* L.	partridgeberry			FACU		HP	W			x	2
12	*Muhlenbergia frondosa* (Poir.) Fernald	wirestem muhly			FAC	C_4	HP	G/W			x	2
12	*Oxalis dillenii* Jacq. ssp. *filipes* (Small) G.Eiten	southern yellow wood-sorrel					HP	G/W			x	1
12	*Oxalis stricta* L.	common yellow wood-sorrel			UPL		HP	G			x	1
12	*Packera aurea* (L.) W.A.Weber & A.Love	golden ragwort			FACW		HP	G/W			x	1
12	*Panicum dichotomiflorum* Michx.	smooth panic grass			FACW–	C_4	HA	G/W			x	2

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12	*Platanthera lacera* (Michx.) G.Don	ragged fringed-orchid			FACW		HP	G/W			x	2
12	*Polygala sanguinea* L.	field milkwort, rose milkwort			FACU		HA	G			x	1
12	*Polygonum erectum* L.	erect knotweed			FACU		HA	G			x	1
12	*Pseudognaphalium obtusifolium* (L.) Hilliard & B.L.Burtt.	fragrant cudweed, rabbit-tobacco					HA HB	G			x	4
12	*Ranunculus abortivus* L.	small-flowered crowfoot			FACW–		HA	G/W			x	2
12	*Rhus glabra* L.	smooth sumac					SD	G			x	4
12	*Rosa carolina* L.	pasture rose			UPL		SD	G			x	6
12	*Salix humilis* Marshall var. *humilis*	upland willow			FACU		SD	G			x	2
12	*Salix humilis* Marshall var. *tristis* (Aiton) Griggs	dwarf upland willow, sage willow			FACU		SD	G			x	4
12	*Salix nigra* Marshall	black willow			FACW+		TD	G/W			x	1
12	*Salvia lyrata* L.	lyre-leaved sage			UPL		HP	G/W			x	1
12	*Scrophularia lanceolata* Pursh	lanceleaf figwort			FACU+		HP	G/W			x	1
12	*Selaginella apoda* (L.) Spring	meadow spikemoss			FACW		HP	G			x	1
12	*Senna hebecarpa* (Fernald) H.S.Irwin & Barneby	northern wild senna			FAC		HP	G			x	1
12	*Sisyrinchium angustifolium* P.Mill.	narrow-leaved blue-eyed-grass			FACW–		HP	G/W			x	2
12	*Smilax herbacea* L.	carrion-flower			FAC		VP	G/W			x	5

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12	*Solidago canadensis* L.	Canada goldenrod			FACU		HP	G/W			x	1
12	*Sporobolus vaginiflorus* (Torr. ex A.Gray) A.W.Wood	poverty grass, poverty dropseed			UPL	C_4	HA	G			x	4
12	*Symphyotrichum laeve* (L.) A.Love & D.Love var. *laeve*	smooth blue aster					HP	G/W			x	7
12	*Symphyotrichum lanceolatum* (Wiegand) Nesom ssp. *lanceolatum* var. *lanceolatum*	panicled aster					HP	G/W			x	1
12	*Symphyotrichum pilosum* (Willd.) Nesom var. *pilosum*	heath aster			UPL		HP	G/W			x	1
12	*Thalictrum pubescens* Pursh	tall meadow-rue			FACW+		HP	G/W			x	2
12	*Viburnum prunifolium* L.	black-haw			FACU		SD TD	G/W			x	3
12	*Viburnum recognitum* Fernald	northern arrow-wood			FACW–		SD	G/W			x	1
	Viola cucullata Aiton	blue marsh violet			FACW+		HP	G/W			x	2
12	*Viola labradorica* Schrank	American dog violet			FACW		HP	G/W			x	1
13	**NO ACTION NEEDED (EXCEPT INCIDENTAL MONITORING) FOR MISCELLANEOUS NATIVE SPECIES. Criteria: native grassland or forest species documented historically at now-destroyed local serpentine barrens**											
13	*Agalinis tenuifolia* (Vahl) Raf.	slender false-foxglove			FAC		HA	G/W				4
13	*Agrimonia gryposepala* Wallr.	tall hairy agrimony harvest-lice			FACU		HP	G/W				2
13	*Amelanchier laevis* Wiegand	smooth serviceberry, smooth shadbush, smooth juneberry					TD	G/W				1

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13	*Amelanchier stolonifera* Wiegand	low serviceberry, low shadbush, low juneberry			FACU		SD	G/W				1
13	*Andropogon gerardii* Vitman	big bluestem, turkeyfoot			FAC–	C_4	HP	G				2
13	*Apocynum androsaemifolium* L.	pink dogbane, spreading dogbane					HP	G/W				1
13	*Aralia spinosa* L.	Hercules'-club, devil's-walkingstick			FAC		TD	G/W				1
13	*Aristida oligantha* Michx.	prairie three-awn				C_4	HA	G				1
13	*Asclepias syriaca* L.	common milkweed			FACU–		HP	G				1
13	*Asplenium platyneuron* (L.) Britton, Stearns & Poggenb.	ebony spleenwort			FACU		HP	G/W				3
13	*Aureolaria pedicularia* (L.) Raf.	cut-leaf false-foxglove					HA	G/W				3
13	*Bidens bipinnata* L.	spanish needles					HA	G/W				1
13	*Bulbostylis capillaris* (L.) C.B.Clarke	sandrush			FACU		HA	G				1
13	*Calystegia spithamaea* (L.) Pursh	low bindweed					VP	G				2
13	*Carex annectens* (E.P.Bicknell) E.P.Bicknell	yellow-fruited sedge			FACW		HP	G/W				2
13	*Carex cephalophora* Willd.	oval-headed sedge			FACU		HP	G/W				1
13	*Carex granularis* Willd. var. *granularis*	limestone meadow sedge			FACW+		HP	G/W				1
13	*Carex hirsutella* Mack.	fuzzy wuzzy sedge					HP	G/W				4

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13	*Carex normalis* Mack.	greater straw sedge			FACU		HP	G/W				4
13	*Celastrus scandens* L.	American bittersweet			FACU–		VW	G/W				2
13	*Chamaecrista nictitans* (L.) Moench	wild sensitive-plant			FACU–		HA	G				3
13	*Cirsium discolor* (Muhl.) Spreng.	field thistle			UPL		HB HP	G				4
13	*Cornus racemosa* Lam.	silky dogwood			FAC–		SD	G/W				1
13	*Crataegus crus-galli* L.	cockspur hawthorn			FACU		SD TD	G/W				1
13	*Crotalaria sagittalis* L.	rattlebox					HA	G/W				4
13	*Cunila origanoides* (L.) Britton	common dittany, stone-mint					HP	G/W				2
13	*Cuphea viscosissima* Jacq.	blue waxweed, clammy cuphea			FAC–		HA	G				1
13	*Cyperus bipartitus* Torr.	slender flatsedge, umbrella sedge			FACW+		HA	G				1
13	*Desmodium paniculatum* (L.) DC	panicled tick-trefoil			UPL		HP	G/W				5
13	*Dichanthelium linearifolium* (Scribn.) Gould	slim-leaved witchgrass				C_3	HP	G/W				1
13	*Eleocharis tenuis* (Willd.) Schult. var. *tenuis*	slender spike-rush			FACW+		HP	G				3
13	*Elymus riparius* Wiegand	riverbank wild-rye			FACW	C_3	HP	G				2
13	*Epilobium angustifolium* L.	fireweed			FAC		HP	G/W				1
13	*Equisetum hyemale* L.	scouring-rush			FACW		HP	G				1
13	*Erythronium americanum* Ker Gawl.	yellow trout-lily					HP	G/W				1
13	*Euphorbia nutans* Lagasca	eyebane			FACU–		HA	G				1

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
13	*Fimbristylis autumnalis* (L.) Roem. & Schult.	slender fimbry			FACW+		HA	G				1
13	*Galium triflorum* Michx.	sweet-scented bedstraw			FACU		HP	G/W				2
13	*Hackelia virginiana* (L.) I.M.Johnst.	beggar's-lice, stickseed			FACU		HB	G/W				1
13	*Helianthus decapetalus* L.	thin-leaved sunflower			FACU		HP	G				1
13	*Helianthus divaricatus* L.	rough sunflower, woodland sunflower					HP	G/W				1
13	*Hieracium scabrum* Michx.	rough hawkweed					HP	G				2
13	*Hypericum gentianoides* (L.) Britton, Stearns & Poggenb.	orange-grass, pineweed			UPL		HA	G				2
13	*Hypericum prolificum* L.	shrubby St. John's-wort			FACU		SD	G				1
13	*Ipomoea pandurata* (L.) G.Mey.	man-of-the-earth, wild potato-vine			FACU		VP	G				1
13	*Krigia virginica* (L.) Willd.	Virginia dwarf dandelion			UPL		HA	G				1
13	*Lactuca biennis* (Moench) Fernald	tall blue lettuce			FACU		HA HB	G/W				2
13	*Lespedeza hirta* (L.) Hornem.	hairy bush-clover, hairy lespedeza					HP	G				2
13	*Lespedeza procumbens* Michx.	trailing bush-clover, trailing lespedeza					HP	G/W				2

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
13	*Lespedeza violacea* (L.) Pers.	violet bush-clover, violet lespedeza					HP	G/W				2
13	*Linum virginianum* L.	slender yellow flax			FACU		HP	G/W				3
13	*Lobelia siphilitica* L.	great blue lobelia			FACW+		HP	G				2
13	*Lonicera sempervirens* L.	trumpet honeysuckle			FACU		VW	G/W				2
13	*Muhlenbergia sylvatica* (Torr.) Torr. ex A.Gray	muhly, woodland dropseed			FAC+	C_4	HP	G/W				2
13	*Myosotis verna* Nutt.	spring forget-me-not, early scorpion-grass			FAC–		HA	G/W				1
13	*Oenothera biennis* L.	common evening-primrose, biennial evening-primrose			FACU–		HB HP	G				1
13	*Oenothera fruticosa* L. ssp. *fruticosa*	sundrops, narrow-leaved evening-primrose			FAC		HP	G				3
13	*Panicum anceps* Michx.	beaked panic grass			FAC	C_4	HP	G				3
13	*Panicum capillare* L.	witchgrass			FAC–	C_4	HA	G				1
13	*Panicum gattingeri* Nash	Gattinger's panic grass			FAC	C_4	HA	G				1
13	*Penstemon hirsutus* (L.) Willd.	northeastern beard-tongue					HP	G				1
13	*Phlox maculata* L.	wild sweet-william			FACW		HP	G				1
13	*Photinia melanocarpa* (Michx.) Robertson & Phipps	black chokeberry			FAC		SD	G/W				1
13	*Polygala verticillata* L. var. *verticillata*	whorled milkwort			UPL		HA	G/W				2

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
13	*Polygonatum biflorum* (Walter) Elliott var. *biflorum*	smooth Solomon's-seal			FACU		HP	W				2
13	*Polygonatum biflorum* (Walter) Elliott var. *commutatum* (Schult. f.) Morong	smooth Solomon's-seal			FACU		HP	W				2
13	*Prenanthes alba* L.	white rattlesnake-root			FACU		HP	G/W				1
13	*Prenanthes trifoliolata* (Cass.) Fernald	gall-of-the-earth					HP	G/W				1
13	*Prunus americana* Marshall	wild plum			FACU–		SD TD	W				1
13	*Pteridium aquilinum* (L.) Kuhn	northern bracken fern			FACU		HP	G/W				3
13	*Sambucus canadensis* L.	American elder			FACW		SD	G/W				1
13	*Sanicula canadensis* L. var. *canadensis*	Canadian sanicle, snakeroot			UPL		HB	W				1
13	*Sanicula canadensis* L. var. *grandis* Fernald	Canadian sanicle, snakeroot			UPL		HB	W				1
13	*Scrophularia marilandica* L.	eastern figwort, carpenter's-square			FACU–		HP	G/W				2
13	*Scutellaria integrifolia* L.	hyssop skullcup			FACW		HP	G/W				1
13	*Scutellaria lateriflora* L.	mad-dog skullcap			FACW+		HP	G/W				1
13	*Sericocarpus asteroides* (L.) Britton, Stearns & Poggenb.	white-topped aster					HP	G/W				1
13	*Silene antirrhina* L.	sleepy catchfly					HA	G/W				1
13	*Solidago caesia* L.	bluestem goldenrod, wreath goldenrod			FACU		HP	W				2

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
13	*Solidago puberula* Nutt.	downy goldenrod			FACU–		HP	G/W				1
13	*Solidago rugosa* P.Mill. ssp. *aspera* (Aiton) Cronquist var. *aspera*	wrinkle-leaf goldenrod			FAC		HP	G				2
13	*Spiranthes lacera* (Raf.) Raf. var. *gracilis* (Bigelow) Luer	southern slender ladies'-tresses			FACU–		HP	G/W				1
13	*Symphyotrichum cordifolium* (L.) Nesom	blue wood aster					HP	G/W				1
13	*Symphyotrichum novae-angliae* (L.) Nesom	New England aster			FAC		HP	G				2
13	*Symphyotrichum patens* (Aiton) Nesom	late purple aster, clasping aster					HP	G/W				3
13	*Thalictrum revolutum* DC	purple meadow-rue, skunk meadow-rue			UPL		HP	G/W				2
13	*Thalictrum thalictroides* (L.) A.J.Eames & B.Boivin	rue anemone, windflower			FACU–		HP	W				2
13	*Vernonia noveboracensis* (L.) Michx.	New York ironweed			FACW+		HP	G/W				1
13	*Viola palmata* L.	early blue violet					HP	G/W				2
13	*Zizia aptera* (A.Gray) Fernald	golden-alexander, meadow zizia			FAC		HP	G/W				1
14	**WATCH AND, IF NECESSARY, CONTROL NONNATIVE BUT NON-INVASIVE SPECIES. Criteria: nonnative species surveyed in 2008 at Pink Hill that are not considered likely to become invasive**											
14	*Achillea millefolium* L.	common yarrow, milfoil	2		FACU		HP	G				
14	*Agrostis gigantea* Roth	redtop	1		FACW–	C_3	HP	G				1

	taxon name & authority	common name(s)	Pink Hill grass-land 2008	Pink Hill edge/ woods 2008	wetland status	C_3/C_4	growth form	habitat prefer-ence	state status	serp-entine fidelity	histor-ical at Pink Hill	histor-ical at 8 serp-entine sites
14	*Agrostis stolonifera* L. var. *palustris* (Huds.) Farw.	carpet bentgrass, creeping bentgrass			FACW	C_3	HP	G				
14	*Anthoxanthum aristatum* Boiss.	annual sweet vernalgrass	1 c*			C_3	HA	G				
14	*Anthoxanthum odoratum* L.	perennial sweet vernalgrass	1 c		FACU	C_3	HP	G				
14	*Dianthus armeria* L.	Deptford-pink	1				HB	G				
14	*Digitaria ischaemum* (Schreb. ex Schweigg.) Schreb. ex Muhl.	smooth crabgrass	1 c			C_4	HA	G				1
14	*Fallopia convolvulus* (L.) A.Love	black bindweed, nimble-will	2 c				VA	G				
14	*Hibiscus syriacus* L.	rose-of-sharon		1 c			SD	G/W				
14	*Linaria vulgaris* Hill	butter-and-eggs	3 c				HP	G				
14	*Malus baccata* (L.) Borkh.	Siberian crabapple		1*			TD	G/W				
14	*Persicaria longiseta* (Bruijn) Kitagawa	low smartweed	1		FACU–		HA	G/W				
14	*Pinus sylvestris* L.	Scots pine		1 c			TE	W				
14	*Prunella vulgaris* L. ssp. *lanceolata* (Barton) Hulten	heal-all, self-heal			FACU+		HP	G/W				1
14	*Rubus phoenicolasius* Maxim.	wineberry	1	2			SD	G/W				
14	*Rumex acetosella* L.	sheep sorrel, sourgrass	1 c		UPL		HP	G				
14	*Setaria faberi* Herrm.	giant foxtail	1 c			C_4	HA	G				
14	*Verbascum blattaria* L.	moth mullein	1				HB	G				1
14	*Verbascum thapsus* L.	common mullein, flannel-plant	1				HB	G				

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Numbers refer to management/restoration action categories (leftmost column of species list).

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elder, American (Adoxaceae) 13
Eleocharis tenuis var. pseudoptera (Cyperaceae) 10
Eleocharis tenuis var. tenuis (Cyperaceae) 13
Elliott's beardgrass (Poaceae) 8
Elymus riparius (Poaceae) 13
English ivy (Araliaceae) 2
Epilobium angustifolium (Onagraceae) 13
Equisetum hyemale (Equisetaceae) 13
Eragrostis pectinacea (Poaceae) 12
Eragrostis spectabilis (Poaceae) 4
Erechtites hieraciifolius (Asteraceae) 11
erect knotweed (Polygonaceae) 12
Erigeron pulchellus (Asteraceae) 12
Erythronium americanum (Liliaceae) 13
Eupatorium perfoliatum (Asteraceae) 12
Euphorbia corollata (Euphorbiaceae) 12
Euphorbia nutans (Euphorbiaceae) 13
Euthamia graminifolia (Asteraceae) 11
Eutrochium fistulosum (Asteraceae) 11
evening-primrose, biennial (Onagraceae) 13
evening-primrose, common (Onagraceae) 13
evening-primrose, little (Onagraceae) 11
evening-primrose, narrow-leaved (Onagraceae) 13
eyebane (Euphorbiaceae) 13
Fagus grandifolia (Fagaceae) 11
fairy-wand (Melanthiaceae) 6
Fallopia convolvulus (Polygonaceae) 14
false nutsedge (Cyperaceae) 12
false Solomon's-seal (Ruscaceae) 12
false-foxglove, cut-leaf (Orobanchaceae) 13
false-foxglove, slender (Orobanchaceae) 13
fern, Christmas (Polypodiaceae) 11
fern, hay-scented (Polypodiaceae) 11
fern, New York (Polypodiaceae) 11
fern, northern bracken (Polypodiaceae) 13
fern, sensitive (Polypodiaceae) 11
fescue, six-weeks (Poaceae) 10
few-flowered nut-rush (Cyperaceae) 7
field beadgrass (Poaceae) 10
field milkwort (Polygalaceae) 12
field thistle (Asteraceae) 13
figwort, eastern (Scrophulariaceae) 13
figwort, lanceleaf (Scrophulariaceae) 12
filbert, American (Betulaceae) 12
Fimbristylis annua (Cyperaceae) 5
Fimbristylis autumnalis (Cyperaceae) 13
fimbry, annual (Cyperaceae) 5
fimbry, slender (Cyperaceae) 13
fireweed (Asteraceae) 11
fireweed (Onagraceae) 13
flannel-plant (Scrophulariaceae) 14
flat-topped goldenrod (Asteraceae) 11
flat-topped white aster (Asteraceae) 10
flatsedge, globe (Cyperaceae) 12
flatsedge, Great Plains (Cyperaceae) 12
flatsedge, slender (Cyperaceae) 13
flax, sandplain wild (Linaceae) 8
flax, slender yellow (Linaceae) 13
flax, yellow (Linaceae) 12
flowering spurge (Euphorbiaceae) 12
fly-away grass (Poaceae) 9, 11
forget-me-not, spring (Boraginaceae) 13
forked rush (Juncaceae) 7
foxtail, giant (Poaceae) 14
foxtail, perennial (Poaceae) 10
Fragaria virginiana (Rosaceae) 12
fragrant cudweed (Asteraceae) 12
Fraxinus americana var. americana (Oleaceae) 11
fringed-orchid, ragged (Orchidaceae) 12
fuzzy wuzzy sedge (Cyperaceae) 13
Galium aparine (Rubiaceae) 12
Galium pilosum (Rubiaceae) 10
Galium triflorum (Rubiaceae) 13
gall-of-the-earth (Asteraceae) 13
Gattinger's panic grass (Poaceae) 13
Gaylussacia baccata (Ericaceae) 12
gentian, soapwort (Gentianaceae) 5
gentian, striped (Gentianaceae) 8

(Numbers refer to management/restoration action categories in leftmost column of species list.)

Gentiana saponaria (Gentianaceae) 5
Gentiana villosa (Gentianaceae) 8
Geranium carolinianum (Geraniaceae) 6
geranium, Carolina (Geraniaceae) 6
giant foxtail (Poaceae) 14
giant-hyssop, purple (Lamiaceae) 10
globe flatsedge (Cyperaceae) 12
goat's-rue (Fabaceae) 10
golden ragwort (Asteraceae) 12
golden-alexander (Apiaceae) 13
goldenrod, bluestem (Asteraceae) 13
goldenrod, Canada (Asteraceae) 12
goldenrod, downy (Asteraceae) 13
goldenrod, flat-topped (Asteraceae) 11
goldenrod, grass-leaved (Asteraceae) 11
goldenrod, gray (Asteraceae) 11
goldenrod, late (Asteraceae) 11
goldenrod, white (Asteraceae) 11
goldenrod, wreath (Asteraceae) 13
goldenrod, wrinkle-leaf (Asteraceae) 11, 13
goosegrass (Rubiaceae) 12
grape-fern, cut-leaved (Ophioglossaceae) 12
grape, pigeon (Vitaceae) 11
grape, summer (Vitaceae) 11
grass-leaved goldenrod (Asteraceae) 11
grass-leaved rush (Juncaceae) 12
grass, deer-tongue (Poaceae) 11
grass, fly-away (Poaceae) 9, 11
grass, poverty (Poaceae) 11, 12
gray birch (Betulaceae) 11
gray goldenrod (Asteraceae) 11
great blue lobelia (Campanulaceae) 13
Great Plains flatsedge (Cyperaceae) 12
greater straw sedge (Cyperaceae) 13
green milkweed (Apocynaceae) 9
greenbrier (Smilacaceae) 3, 11
greenbrier, cat (Smilacaceae) 11
groundsel, Appalachian (Asteraceae) 4
Hackelia virginiana (Boraginaceae) 13
hairgrass, tufted (Poaceae) 7
hairy angelica (Apiaceae) 9
hairy beadgrass (Poaceae) 8
hairy bedstraw (Rubiaceae) 10
hairy bush-clover (Fabaceae) 13
hairy lespedeza (Fabaceae) 13
harvest-lice (Rosaceae) 13
hawkweed (Asteraceae) 12
hawkweed, rough (Asteraceae) 13
hawthorn, cockspur (Rosaceae) 13
hay-scented fern (Polypodiaceae) 11
hazelnut (Betulaceae) 12
heal-all (Lamiaceae) 14
heath aster (Asteraceae) 12
Hedera helix (Araliaceae) 2
Helenium autumnale (Asteraceae) 12
Helianthemum bicknellii (Cistaceae) 7
Helianthus decapetalus (Asteraceae) 13
Helianthus divaricatus (Asteraceae) 13
Helianthus giganteus (Asteraceae) 12
Helianthus strumosus (Asteraceae) 6
Heliopsis helianthoides (Asteraceae) 9
Heller's witchgrass (Poaceae) 4
Hercules'-club (Araliaceae) 13
Hibiscus syriacus (Malvaceae) 14
hickory, mockernut (Juglandaceae) 11
Hieracium gronovii (Asteraceae) 12
Hieracium scabrum (Asteraceae) 13
Hieracium venosum (Asteraceae) 12
highbush blueberry (Ericaceae) 11
hollow-stemmed joe-pye-weed (Asteraceae) 11
holly, American (Aquifoliaceae) 11
honeysuckle, Amur (Caprifoliaceae) 1
honeysuckle, Japanese (Caprifoliaceae) 1
honeysuckle, trumpet (Caprifoliaceae) 13
horrible thistle (Asteraceae) 8
Houstonia caerulea (Rubiaceae) 4
huckleberry, black (Ericaceae) 12
Hypericum gentianoides (Hypericaceae) 13
Hypericum prolificum (Hypericaceae) 13
Hypericum punctatum (Hypericaceae) 11
Hypoxis hirsuta (Hypoxidaceae) 12
hyssop skullcup (Lamiaceae) 13
Ilex opaca (Aquifoliaceae) 11
Indian paintbrush (Orobanchaceae) 5
Indian-grass (Poaceae) 4
indigo, wild (Fabaceae) 5
Ipomoea pandurata (Convolvulaceae) 13
ironweed, Appalachian (Asteraceae) 8
ironweed, New York (Asteraceae) 13
ironweed, tawny (Asteraceae) 8
ivy, English (Araliaceae) 2
Japanese barberry (Berberidaceae) 1
Japanese honeysuckle (Caprifoliaceae) 1
Japanese stiltgrass (Poaceae) 1
joe-pye-weed (Asteraceae) 11
joe-pye-weed, hollow-stemmed (Asteraceae) 11
Juglans cinerea (Juglandaceae) 11
Juncus dichotomus (Juncaceae) 7
Juncus marginatus (Juncaceae) 12
Juncus secundus (Juncaceae) 4
Juncus tenuis var. tenuis (Juncaceae) 11
juneberry, low (Rosaceae) 13
juneberry, smooth (Rosaceae) 13
Juniperus virginiana (Cupressaceae) 11

knotweed, erect (Polygonaceae) 12
knotweed, slender (Polygonaceae)..... 4
Krigia virginica (Asteraceae)..... 13
Lactuca biennis (Asteraceae)..... 13
ladies'-tresses, slender (Orchidaceae)..... 8
ladies'-tresses, southern slender (Orchidaceae)..... 13
ladies'-tresses, spring (Orchidaceae) 5
lanceleaf figwort (Scrophulariaceae) 12
late goldenrod (Asteraceae) 11
late purple aster (Asteraceae)..... 13
leaf-cup (Asteraceae) 8
Lechea pulchella (Cistaceae) 10
Leersia virginica (Poaceae) 11
Leggett's pinweed (Cistaceae)..... 10
Lespedeza capitata (Fabaceae) 5
Lespedeza hirta (Fabaceae)..... 13
Lespedeza hirta x intermedia (Fabaceae)..... 10
Lespedeza procumbens (Fabaceae)..... 13
Lespedeza repens (Fabaceae)..... 10
Lespedeza violacea (Fabaceae)..... 13
Lespedeza virginica (Fabaceae)..... 9
lespedeza, hairy (Fabaceae) 13
lespedeza, round-headed (Fabaceae)..... 5
lespedeza, slender (Fabaceae)..... 9
lespedeza, trailing (Fabaceae)..... 13
lespedeza, violet (Fabaceae) 13
lettuce, tall blue (Asteraceae)..... 13
Liatris spicata var. spicata (Asteraceae) 10
Lilium canadense ssp. canadense (Liliaceae)..... 12
Lilium philadelphicum (Liliaceae)..... 4
lily, Canada (Liliaceae)..... 12
lily, wood (Liliaceae) 4
limestone meadow sedge (Cyperaceae) 13
Linaria vulgaris (Plantaginaceae)..... 14
Lindera benzoin (Lauraceae) 11
Linum intercursum (Linaceae)..... 8
Linum medium var. texanum (Linaceae)..... 12
Linum virginianum (Linaceae)..... 13
lion's-foot (Asteraceae)..... 7
Liparis loeselii (Orchidaceae)..... 12
Liquidambar styraciflua (Altingiaceae)..... 11
Liriodendron tulipifera (Magnoliaceae) 11
little bluestem (Poaceae) 4
little evening-primrose (Onagraceae)..... 11
Lobelia siphilitica (Campanulaceae) 13
Lobelia spicata var. spicata (Campanulaceae) 4
lobelia, great blue (Campanulaceae)..... 13
lobelia, spiked (Campanulaceae) 4
locust, black (Fabaceae)..... 1
long-haired panic grass (Poaceae)..... 8
Lonicera japonica (Caprifoliaceae) 1
Lonicera maackii (Caprifoliaceae)..... 1
Lonicera sempervirens (Caprifoliaceae)..... 13
lopsided rush (Juncaceae) 4
lovegrass, Carolina (Poaceae)..... 12
lovegrass, purple (Poaceae) 4
low bindweed (Convolvulaceae) 13
low juneberry (Rosaceae) 13
low serviceberry (Rosaceae)..... 13
low shadbush (Rosaceae)..... 13
low smartweed (Polygonaceae) 14
low sweet blueberry (Ericaceae)..... 11
lowbush blueberry (Ericaceae) 11
Luzula echinata (Juncaceae)..... 12
Lyonia ligustrina (Ericaceae) 4
lyre-leaved rockcress (Brassicaceae)..... 4
lyre-leaved sage (Lamiaceae) 12
mad-dog skullcap (Lamiaceae)..... 13
Maianthemum racemosum (Ruscaceae) 12
maleberry (Ericaceae)..... 4
Malus baccata (Rosaceae)..... 14
Malus coronaria (Rosaceae)..... 12
man-of-the-earth (Convolvulaceae)..... 13
maple, red (Sapindaceae)..... 3
marsh-pink, common (Gentianaceae)..... 4
Maryland tick-clover (Fabaceae)..... 10
meadow spikemoss (Selaginellaceae)..... 12
meadow zizia (Apiaceae)..... 13
meadow-rue, purple (Ranunculaceae) 13
meadow-rue, skunk (Ranunculaceae)..... 13
meadow-rue, tall (Ranunculaceae) 12
meadow-sweet (Rosaceae)..... 9
mercury, common three-seeded (Euphorbiaceae)..... 12
Mexican muhly satingrass (Poaceae)..... 4
Microstegium vimineum (Poaceae)..... 1
milfoil (Asteraceae) 14
milkweed, common (Apocynaceae) 13
milkweed, green (Apocynaceae) 9
milkweed, purple (Apocynaceae) 10
milkweed, whorled (Apocynaceae) 5
milkwort, field (Polygalaceae)..... 12
milkwort, rose (Polygalaceae) 12
milkwort, whorled (Polygalaceae)..... 13
Minuartia michauxii (Caryophyllaceae)..... 5
Mitchella repens (Rubiaceae) 12
mockernut hickory (Juglandaceae) 11
moss phlox (Polemoniaceae) 4
moss-pink (Polemoniaceae)..... 4
moth mullein (Scrophulariaceae)..... 14
mountain-mint, narrow-leaved (Lamiaceae) 11
mountain-mint, slender (Lamiaceae) 11
Muhlenbergia frondosa (Poaceae)..... 12
Muhlenbergia mexicana (Poaceae)..... 4
Muhlenbergia sylvatica (Poaceae)..... 13
muhly (Poaceae) 13

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muhly, Mexican (Poaceae) 4
muhly, wirestem (Poaceae) 12
mullein, common (Scrophulariaceae) 14
mullein, moth (Scrophulariaceae) 14
multiflora rose (Rosaceae) 1
Myosotis verna (Boraginaceae) 13
narrow-leaved blue-eyed-grass (Iridaceae) 12
narrow-leaved evening-primrose (Onagraceae) 13
narrow-leaved mountain-mint (Lamiaceae) 11
needles, spanish (Asteraceae) 13
needletip blue-eyed-grass (Iridaceae) 9
New England aster (Asteraceae) 13
New Jersey tea (Rhamnaceae) 4
New York fern (Polypodiaceae) 11
New York ironweed (Asteraceae) 13
nimble-will (Polygonaceae) 14
northeastern beard-tongue (Plantaginaceae) 13
northern adder's-tongue (Ophioglossaceae) 6
northern arrow-wood (Adoxaceae) 12
northern bracken fern (Polypodiaceae) 13
northern dewberry (Rosaceae) 11
northern red oak (Fagaceae) 11
northern wild senna (Fabaceae) 12
nut-rush (Cyperaceae) 7
nut-rush, few-flowered (Cyperaceae) 7
nutsedge, false (Cyperaceae) 12
Nuttall's bush-clover (Fabaceae) 10
Nuttall's tick-trefoil (Fabaceae) 8
Nyssa sylvatica (Nyssaceae) 11
oak, bear (Fagaceae) 9
oak, black (Fagaceae) 11
oak, blackjack (Fagaceae) 4
oak, bush (Fagaceae) 4
oak, dwarf chestnut (Fagaceae) 5
oak, northern red (Fagaceae) 11
oak, post (Fagaceae) 5
oak, scarlet (Fagaceae) 11
oak, scrub (Fagaceae) 9
oak, white (Fagaceae) 11
oatgrass, poverty (Poaceae) 11
Oenothera biennis (Onagraceae) 13
Oenothera fruticosa ssp. fruticosa (Onagraceae) 13
Oenothera perennis (Onagraceae) 11
old-field cinquefoil (Rosaceae) 11
Onoclea sensibilis (Polypodiaceae) 11
open-field sedge (Cyperaceae) 6
Ophioglossum pusillum (Ophioglossaceae) 6
orange-grass (Hypericaceae) 13
Oriental bittersweet (Celastraceae) 1
oval-headed sedge (Cyperaceae) 13
overlooked pussytoe (Asteraceae) 12
ox-eye (Asteraceae) 9
ox-eye, smooth (Asteraceae) 9
Oxalis dillenii ssp. filipes (Oxalidaceae) 12
Oxalis stricta (Oxalidaceae) 12
Packera anonyma (Asteraceae) 4
Packera aurea (Asteraceae) 12
paintbrush, Indian (Orobanchaceae) 5
panic grass, annulus (Poaceae) 5
panic grass, beaked (Poaceae) 13
panic grass, Bosc's (Poaceae) 10
panic grass, cypress (Poaceae) 12
panic grass, Gattinger's (Poaceae) 13
panic grass, long-haired (Poaceae) 8
panic grass, Philadelphia (Poaceae) 5
panic grass, poverty (Poaceae) 10
panic grass, round-fruited (Poaceae) 4
panic grass, round-seeded (Poaceae) 4
panic grass, Scribner's (Poaceae) 4
panic grass, smooth (Poaceae) 12
panic grass, Yadkin River (Poaceae) 8
panicled aster (Asteraceae) 12
panicled tick-trefoil (Fabaceae) 13
Panicum anceps (Poaceae) 13
Panicum capillare (Poaceae) 13
Panicum dichotomiflorum (Poaceae) 12
Panicum gattingeri (Poaceae) 13
Panicum philadelphicum (Poaceae) 5
parasol sedge (Cyperaceae) 6
Parlin's pussytoe (Asteraceae) 6
Parthenocissus quinquefolia (Vitaceae) 11
partridge-pea (Fabaceae) 10
partridgeberry (Rubiaceae) 12
Paspalum laeve (Poaceae) 10
Paspalum setaceum var. muhlenbergii (Poaceae) 8
pasture rose (Rosaceae) 12
pasture thistle (Asteraceae) 12
path rush (Juncaceae) 11
pencil-flower (Fabaceae) 8
Pennsylvania sedge (Cyperaceae) 11
Pennsylvania smartweed (Polygonaceae) 11
Penstemon hirsutus (Plantaginaceae) 13
perennial foxtail (Poaceae) 10
perennial sweet vernalgrass (Poaceae) 14
periwinkle (Apocynaceae) 2
Persicaria longiseta (Polygonaceae) 14
Persicaria pensylvanica (Polygonaceae) 11
Philadelphia panic grass (Poaceae) 5
Phlox maculata (Polemoniaceae) 13
Phlox pilosa (Polemoniaceae) 8

Phlox subulata ssp. subulata (Polemoniaceae) 4
phlox, creeping (Polemoniaceae) 4
phlox, downy (Polemoniaceae) 8
phlox, moss (Polemoniaceae) 4
phlox, prairie (Polemoniaceae) 8
Photinia melanocarpa (Rosaceae) 13
pigeon grape (Vitaceae) 11
pilewort (Asteraceae) 11
pine, eastern white (Pinaceae) 11
pine, Scots (Pinaceae) 14
pine, Virginia (Pinaceae) 3
pineweed (Hypericaceae) 13
pink dogbane (Apocynaceae) 13
pinkweed (Polygonaceae) 11
Pinus strobus (Pinaceae) 11
Pinus sylvestris (Pinaceae) 14
Pinus virginiana (Pinaceae) 3
pinweed, Leggett's (Cistaceae) 10
pinxter-flower (Ericaceae) 11
pipsissewa (Ericaceae) 11
plain ragwort (Asteraceae) 4
plantain-leaved pussytoe (Asteraceae) 11
Platanthera lacera (Orchidaceae) 12
plum, wild (Rosaceae) 13
poison-ivy (Anacardiaceae) 11
Polygala sanguinea (Polygalaceae) 12
Polygala verticillata var. verticillata (Polygalaceae) 13
Polygonatum biflorum var. biflorum (Ruscaceae) 13
Polygonatum biflorum var. commutatum (Ruscaceae) 13
Polygonum erectum (Polygonaceae) 12
Polygonum tenue (Polygonaceae) 4
Polystichum acrostichoides (Polypodiaceae) 11
Populus grandidentata (Salicaceae) 11
post oak (Fagaceae) 5
potato-vine, wild (Convolvulaceae) 13
Potentilla canadensis (Rosaceae) 11
Potentilla simplex (Rosaceae) 11
poverty dropseed (Poaceae) 12
poverty grass (Poaceae) 11, 12
poverty oatgrass (Poaceae) 11
poverty panic grass (Poaceae) 10
poverty three-awn (Poaceae) 11
prairie phlox (Polemoniaceae) 8
prairie senna (Fabaceae) 10
prairie three-awn (Poaceae) 13
prairie wedgegrass (Poaceae) 5
Prenanthes alba (Asteraceae) 13
Prenanthes serpentaria (Asteraceae) 7
Prenanthes trifoliolata (Asteraceae) 13
prickly dewberry (Rosaceae) 11
prince's-pine (Ericaceae) 11
Prunella vulgaris ssp. lanceolata (Lamiaceae) 14
Prunus americana (Rosaceae) 13
Prunus avium (Rosaceae) 2
Prunus serotina (Rosaceae) 11
Pseudognaphalium obtusifolium (Asteraceae) 12
Pteridium aquilinum (Polypodiaceae) 13
purple giant-hyssop (Lamiaceae) 10
purple lovegrass (Poaceae) 4
purple meadow-rue (Ranunculaceae) 13
purple milkweed (Apocynaceae) 10
purpletop (Poaceae) 11
pussytoe, overlooked (Asteraceae) 12
pussytoe, Parlin's (Asteraceae) 6
pussytoe, plantain-leaved (Asteraceae) 11
Pycnanthemum tenuifolium (Lamiaceae) 11
Quaker-ladies (Rubiaceae) 4
Quercus alba (Fagaceae) 11
Quercus coccinea (Fagaceae) 11
Quercus ilicifolia (Fagaceae) 9
Quercus marilandica (Fagaceae) 4
Quercus marilandica x velutina (Fagaceae) 4
Quercus prinoides (Fagaceae) 5
Quercus rubra (Fagaceae) 11
Quercus stellata (Fagaceae) 5
Quercus velutina (Fagaceae) 11
rabbit-tobacco (Asteraceae) 12
ragged fringed-orchid (Orchidaceae) 12
ragweed, common (Asteraceae) 11
ragwort, golden (Asteraceae) 12
ragwort, plain (Asteraceae) 4
Ranunculus abortivus (Ranunculaceae) 12
raspberry, black (Rosaceae) 11
rattlebox (Fabaceae) 13
rattlesnake-root, white (Asteraceae) 13
rattlesnake-weed (Asteraceae) 12
red maple (Sapindaceae) 3
red-cedar, eastern (Cupressaceae) 11
redtop (Poaceae) 14
reflexed sedge (Cyperaceae) 9
Rhododendron periclymenoides (Ericaceae) 11
Rhus glabra (Anacardiaceae) 12
riverbank wild-rye (Poaceae) 13
robin's-plantain (Asteraceae) 12
Robinia pseudoacacia (Fabaceae) 1
rock sandwort (Caryophyllaceae) 5
rockcress, lyre-leaved (Brassicaceae) 4
rockrose, Bicknell's hoary (Cistaceae) 7
Rosa carolina (Rosaceae) 12
Rosa multiflora (Rosaceae) 1
Rosa virginiana (Rosaceae) 8
rose milkwort (Polygalaceae) 12

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rose-of-sharon (Malvaceae) 14
rose-pink (Gentianaceae) 4
rose, multiflora (Rosaceae) 1
rose, pasture (Rosaceae) 12
rose, Virginia wild (Rosaceae) 8
rosette grass, tapered (Poaceae) 4
rough buttonweed (Rubiaceae) 10
rough hawkweed (Asteraceae) 13
rough sunflower (Asteraceae) 13
rough-leaved sunflower (Asteraceae) 6
round-fruited panic grass (Poaceae) 4
round-headed bush-clover (Fabaceae) 5
round-headed lespedeza (Fabaceae) 5
round-leaved greenbrier (Smilacaceae) 3
round-seeded panic grass (Poaceae) 4
Rubus allegheniensis (Rosaceae) 11
Rubus flagellaris (Rosaceae) 11
Rubus occidentalis (Rosaceae) 11
Rubus pensilvanicus (Rosaceae) 11
Rubus phoenicolasius (Rosaceae) 14
rue anemone (Ranunculaceae) 13
Rumex acetosella (Polygonaceae) 14
rush, forked (Juncaceae) 7
rush, grass-leaved (Juncaceae) 12
rush, lopsided (Juncaceae) 4
rush, path (Juncaceae) 11
Sabatia angularis (Gentianaceae) 4
sage willow (Salicaceae) 12
sage, lyre-leaved (Lamiaceae) 12
Salix humilis var. humilis (Salicaceae) 12
Salix humilis var. tristis (Salicaceae) 12
Salix nigra (Salicaceae) 12
Salvia lyrata (Lamiaceae) 12
Sambucus canadensis (Adoxaceae) 13
sand sedge (Cyperaceae) 12
sandplain wild flax (Linaceae) 8
sandrush (Cyperaceae) 13
sandwort, rock (Caryophyllaceae) 5
Sanguisorba canadensis (Rosaceae) 9
sanicle, Canadian (Apiaceae) 13
Sanicula canadensis var. canadensis (Apiaceae) 13
Sanicula canadensis var. grandis (Apiaceae) 13
sassafras (Lauraceae) 3
Sassafras albidum (Lauraceae) 3
Saxifraga virginiensis (Saxifragaceae) 4
saxifrage, early (Saxifragaceae) 4
scarlet oak (Fagaceae) 11
Schizachyrium scoparium var. scoparium (Poaceae) 4
Scleria pauciflora (Cyperaceae) 7
Scleria triglomerata (Cyperaceae) 7
scorpion-grass, early (Boraginaceae) 13
Scots pine (Pinaceae) 14
scouring-rush (Equisetaceae) 13
Scribner's panic grass (Poaceae) 4
Scrophularia lanceolata (Scrophulariaceae) 12
Scrophularia marilandica (Scrophulariaceae) 13
scrub oak (Fagaceae) 9
Scutellaria integrifolia (Lamiaceae) 13
Scutellaria lateriflora (Lamiaceae) 13
Scutellaria serrata (Lamiaceae) 5
sedge, Bicknell's (Cyperaceae) 7
sedge, blue (Cyperaceae) 4
sedge, bog (Cyperaceae) 12
sedge, broad-leaf (Cyperaceae) 11
sedge, broom (Cyperaceae) 12
sedge, eastern narrow-leaved (Cyperaceae) 12
sedge, fuzzy wuzzy (Cyperaceae) 13
sedge, greater straw (Cyperaceae) 13
sedge, limestone meadow (Cyperaceae) 13
sedge, open-field (Cyperaceae) 6
sedge, oval-headed (Cyperaceae) 13
sedge, parasol (Cyperaceae) 6
sedge, Pennsylvania (Cyperaceae) 11
sedge, reflexed (Cyperaceae) 9
sedge, sand (Cyperaceae) 12
sedge, slender loose-flower (Cyperaceae) 12
sedge, umbrella (Cyperaceae) 12, 13
sedge, yellow-fruited (Cyperaceae) 13
Selaginella apoda (Selaginellaceae) 12
self-heal (Lamiaceae) 14
Senna hebecarpa (Fabaceae) 12
senna, northern wild (Fabaceae) 12
senna, prairie (Fabaceae) 10
sensitive fern (Polypodiaceae) 11
sensitive-plant, wild (Fabaceae) 13
Sericocarpus asteroides (Asteraceae) 13
serpentine aster (Asteraceae) 4
serviceberry, low (Rosaceae) 13
serviceberry, smooth (Rosaceae) 13
Setaria faberi (Poaceae) 14
Setaria parviflora (Poaceae) 10
shadbush, low (Rosaceae) 13
shadbush, smooth (Rosaceae) 13
sheep sorrel (Polygonaceae) 14
showy skullcap (Lamiaceae) 5
shrubby St. John's-wort (Hypericaceae) 13
Siberian crabapple (Rosaceae) 14
Silene antirrhina (Caryophyllaceae) 13
Silene stellata (Caryophyllaceae) 6
silky dogwood (Cornaceae) 13
silver-rod (Asteraceae) 11

Sisyrinchium angustifolium (Iridaceae) 12
Sisyrinchium mucronatum (Iridaceae) 9
six-weeks fescue (Poaceae)..... 10
skullcap, mad-dog (Lamiaceae) 13
skullcap, showy (Lamiaceae)..... 5
skullcup, hyssop (Lamiaceae) 13
skunk meadow-rue (Ranunculaceae) 13
sleepy catchfly (Caryophyllaceae) 13
slender beadgrass (Poaceae)..... 8
slender bush-clover (Fabaceae)..... 9
slender crabgrass (Poaceae) 10
slender false-foxglove (Orobanchaceae)..... 13
slender fimbry (Cyperaceae)..... 13
slender flatsedge (Cyperaceae) 13
slender knotweed (Polygonaceae)..... 4
slender ladies'-tresses (Orchidaceae)..... 8
slender lespedeza (Fabaceae) 9
slender loose-flower sedge (Cyperaceae) 12
slender mountain-mint (Lamiaceae) 11
slender spike-rush (Cyperaceae) 10, 13
slender three-awn (Poaceae) 4
slender yellow flax (Linaceae)..... 13
slim-leaved witchgrass (Poaceae) 13
slimspike three-awn (Poaceae)..... 4
small sundrops (Onagraceae) 11
small-flowered crowfoot (Ranunculaceae) 12
small-leaved white-snakeroot (Asteraceae) 7
Smallanthus uvedalia (Asteraceae)..... 8
smartweed, low (Polygonaceae) 14
smartweed, Pennsylvania (Polygonaceae) 11
Smilax glauca (Smilacaceae) 11
Smilax herbacea (Smilacaceae) 12
Smilax rotundifolia (Smilacaceae)..... 3
smooth blue aster (Asteraceae) 12
smooth crabgrass (Poaceae)..... 14
smooth juneberry (Rosaceae)..... 13
smooth ox-eye (Asteraceae)..... 9
smooth panic grass (Poaceae) 12
smooth serviceberry (Rosaceae) 13
smooth shadbush (Rosaceae) 13
smooth Solomon's-seal (Ruscaceae) 13
smooth sumac (Anacardiaceae) 12
snakeroot (Apiaceae)..... 13
snakeroot, common white (Asteraceae)..... 11
sneezeweed, common (Asteraceae) 12
soapwort gentian (Gentianaceae)..... 5
Solidago altissima (Asteraceae)..... 11
Solidago bicolor (Asteraceae)..... 11
Solidago caesia (Asteraceae)..... 13
Solidago canadensis (Asteraceae) 12
Solidago nemoralis (Asteraceae) 11
Solidago puberula (Asteraceae)..... 13
Solidago rugosa ssp. aspera var. aspera (Asteraceae) 13
Solidago rugosa ssp. rugosa var. rugosa (Asteraceae)..... 11
Solomon's-plume (Ruscaceae) 12
Solomon's-seal, false (Ruscaceae) 12
Solomon's-seal, smooth (Ruscaceae) 13
Sorghastrum nutans (Poaceae) 4
sorrel, sheep (Polygonaceae) 14
sourgrass (Polygonaceae) 14
sourgum (Nyssaceae)..... 11
southern arrow-wood (Adoxaceae)..... 11
southern slender ladies'-tresses (Orchidaceae) 13
southern yellow wood-sorrel (Oxalidaceae)..... 12
spanish needles (Asteraceae) 13
Sphenopholis obtusata var. obtusata (Poaceae) 5
spicebush (Lauraceae) 11
spike-rush, slender (Cyperaceae)..... 10, 13
spiked lobelia (Campanulaceae) 4
spikemoss, meadow (Selaginellaceae)..... 12
Spiraea latifolia (Rosaceae) 9
Spiranthes lacera var. gracilis (Orchidaceae) 13
Spiranthes tuberosa (Orchidaceae)..... 8
Spiranthes vernalis (Orchidaceae)..... 5
spleenwort, ebony (Polypodiaceae) 13
Sporobolus vaginiflorus (Poaceae) 12
spotted St. John's-wort (Hypericaceae)..... 11
spreading dogbane (Apocynaceae) 13
spring forget-me-not (Boraginaceae)..... 13
spring ladies'-tresses (Orchidaceae) 5
spurge, flowering (Euphorbiaceae)..... 12
St. John's-wort, shrubby (Hypericaceae)..... 13
St. John's-wort, spotted (Hypericaceae)..... 11
stagger-bush (Ericaceae)..... 4
star-grass, yellow (Hypoxidaceae)..... 12
starry campion (Caryophyllaceae)..... 6
stickseed (Boraginaceae) 13
stickywilly (Rubiaceae) 12
stiff tick-trefoil (Fabaceae) 8
stiltgrass, Japanese (Poaceae) 1
stone-mint (Lamiaceae) 13
strawberry, wild (Rosaceae) 12
striped gentian (Gentianaceae) 8
Stylosanthes biflora (Fabaceae)..... 8
sumac, smooth (Anacardiaceae) 12
summer grape (Vitaceae)..... 11
sundrops (Onagraceae) 13
sundrops, small (Onagraceae)..... 11
sunflower, rough (Asteraceae)..... 13
sunflower, rough-leaved (Asteraceae) 6
sunflower, swamp (Asteraceae)..... 12
sunflower, thin-leaved (Asteraceae) 13
sunflower, woodland (Asteraceae) 13

(Numbers refer to management/restoration action categories in leftmost column of species list.)

swamp sunflower (Asteraceae)....12
swamp thistle (Asteraceae)....6
sweet birch (Betulaceae)....11
sweet cherry (Rosaceae)....2
sweet crabapple (Rosaceae)....12
sweet-fern (Myricaceae)....12
sweet-scented bedstraw (Rubiaceae)....13
sweet-william, wild (Polemoniaceae)....13
sweetgum (Altingiaceae)....11
Symphyotrichum cordifolium (Asteraceae)....13
Symphyotrichum depauperatum (Asteraceae)....4
Symphyotrichum ericoides ssp. ericoides (Asteraceae)....8
Symphyotrichum laeve var. laeve (Asteraceae)....12
Symphyotrichum lanceolatum ssp. lanceolatum var. lanceolatum (Asteraceae)....12
Symphyotrichum lateriflorum (Asteraceae)....11
Symphyotrichum novae-angliae (Asteraceae)....13
Symphyotrichum patens (Asteraceae)....13
Symphyotrichum pilosum var. pilosum (Asteraceae)....12
Symphyotrichum undulatum (Asteraceae)....11
tall blue lettuce (Asteraceae)....13
tall hairy agrimony (Rosaceae)....13
tall meadow-rue (Ranunculaceae)....12
tall tick-trefoil (Fabaceae)....8
tapered rosette grass (Poaceae)....4
tawny ironweed (Asteraceae)....8
tea, New Jersey (Rhamnaceae)....4
Tephrosia virginiana (Fabaceae)....10
Thalictrum pubescens (Ranunculaceae)....12
Thalictrum revolutum (Ranunculaceae)....13
Thalictrum thalictroides (Ranunculaceae)....13
Thelypteris noveboracensis (Polypodiaceae)....11
thin-leaved sunflower (Asteraceae)....13
thistle, Canada (Asteraceae)....1
thistle, field (Asteraceae)....13
thistle, horrible (Asteraceae)....8
thistle, pasture (Asteraceae)....12
thistle, swamp (Asteraceae)....6
thistle, yellow (Asteraceae)....8
three-awn, arrow-feather (Poaceae)....4
three-awn, churchmouse (Poaceae)....11
three-awn, poverty (Poaceae)....11
three-awn, prairie (Poaceae)....13
three-awn, slender (Poaceae)....4
three-awn, slimspike (Poaceae)....4
tick-clover, Maryland (Fabaceae)....10
tick-trefoil, Nuttall's (Fabaceae)....8
tick-trefoil, panicled (Fabaceae)....13
tick-trefoil, stiff (Fabaceae)....8
tick-trefoil, tall (Fabaceae)....8
ticklegrass (Poaceae)....9, 11
toadflax, bastard (Santalaceae)....9
Toxicodendron radicans (Anacardiaceae)....11
trailing bush-clover (Fabaceae)....13
trailing lespedeza (Fabaceae)....13
tree-of-heaven (Simaroubaceae)....2
Tridens flavus (Poaceae)....11
trout-lily, yellow (Liliaceae)....13
trumpet honeysuckle (Caprifoliaceae)....13
trumpetweed (Asteraceae)....11
tufted hairgrass (Poaceae)....7
tuliptree (Magnoliaceae)....11
tumblegrass (Poaceae)....4
tupelo (Nyssaceae)....11
turkeyfoot (Poaceae)....13
twayblade, yellow (Orchidaceae)....12
umbrella sedge (Cyperaceae)....12, 13
upland bentgrass (Poaceae)....11
upland willow (Salicaceae)....12
Vaccinium angustifolium (Ericaceae)....11
Vaccinium corymbosum (Ericaceae)....11
Vaccinium pallidum (Ericaceae)....11
Vaccinium stamineum (Ericaceae)....11
Verbascum blattaria (Scrophulariaceae)....14
Verbascum thapsus (Scrophulariaceae)....14
vernalgrass, annual sweet (Poaceae)....14
vernalgrass, perennial sweet (Poaceae)....14
Vernonia glauca (Asteraceae)....8
Vernonia noveboracensis (Asteraceae)....13
Veronicastrum virginicum (Plantaginaceae)....10
Viburnum dentatum (Adoxaceae)....11
Viburnum prunifolium (Adoxaceae)....12
Viburnum recognitum (Adoxaceae)....12
Vinca minor (Apocynaceae)....2
Viola cucullata (Violaceae)....12
Viola labradorica (Violaceae)....12
Viola palmata (Violaceae)....13
Viola sagittata var. sagittata (Violaceae)....4
violet bush-clover (Fabaceae)....13
violet lespedeza (Fabaceae)....13
violet, American dog (Violaceae)....12
violet, arrow-leaved (Violaceae)....4
violet, blue marsh (Violaceae)....12
violet, early blue (Violaceae)....13
Virginia dwarf dandelion (Asteraceae)....13
Virginia pine (Pinaceae)....3
Virginia wild rose (Rosaceae)....8
Virginia-creeper (Vitaceae)....11
Vitis aestivalis (Vitaceae)....11

Vulpia octoflora var. glauca (Poaceae) 10
waxweed, blue (Lythraceae) 13
wedgegrass, prairie (Poaceae)..... 5
whip-grass (Cyperaceae)..... 7
white ash (Oleaceae) 11
white goldenrod (Asteraceae) 11
white heath aster (Asteraceae) 8
white oak (Fagaceae) 11
white rattlesnake-root (Asteraceae) 13
white-snakeroot, small-leaved (Asteraceae) 7
white-topped aster (Asteraceae)..... 13
whitegrass (Poaceae)..... 11
whorled milkweed (Apocynaceae)..... 5
whorled milkwort (Polygalaceae) 13
wild black cherry (Rosaceae)..... 11
wild indigo (Fabaceae)..... 5
wild plum (Rosaceae)..... 13
wild potato-vine (Convolvulaceae)..... 13
wild sensitive-plant (Fabaceae)..... 13
wild strawberry (Rosaceae)..... 12
wild sweet-william (Polemoniaceae)..... 13
wild-rye, riverbank (Poaceae)..... 13
willow, black (Salicaceae) 12
willow, dwarf upland (Salicaceae)..... 12
willow, sage (Salicaceae)..... 12
willow, upland (Salicaceae) 12
windflower (Ranunculaceae)..... 13
wineberry (Rosaceae) 14
wirestem muhly (Poaceae)..... 12
witchgrass, Heller's (Poaceae)..... 4
witchgrass, slim-leaved (Poaceae)..... 13
witchgrass (Poaceae) 13
wood lily (Liliaceae)..... 4
wood-sorrel, common yellow (Oxalidaceae)..... 12
wood-sorrel, southern yellow (Oxalidaceae)..... 12
woodbine (Vitaceae)..... 11
woodland dropseed (Poaceae) 13
woodland sunflower (Asteraceae) 13
woodrush, common (Juncaceae)..... 12
wreath goldenrod (Asteraceae) 13
wrinkle-leaf goldenrod (Asteraceae) 11, 13
Yadkin River panic grass (Poaceae) 8
yarrow, common (Asteraceae)..... 14
yellow flax (Linaceae) 12
yellow star-grass (Hypoxidaceae)..... 12
yellow thistle (Asteraceae) 8
yellow trout-lily (Liliaceae)..... 13
yellow twayblade (Orchidaceae) 12
yellow-fruited sedge (Cyperaceae)..... 13
yellow-poplar (Magnoliaceae)..... 11
Zizia aptera (Apiaceae) 13
zizia, meadow (Apiaceae)..... 13