Management Plan for Goat Hill Wild Plant Sanctuary

ON THE COVER

Round-leaved fameflower (*Phemeranthus teretifolius*)
Photograph by: Charlie Eichelberger, Pennsylvania Natural Heritage Program

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Mary Ann Furedi[1], Roger Latham[2], Tony Davis[1], and Greg Podniesinski[1]

[1] Pennsylvania Natural Heritage Program
Western Pennsylvania Conservancy
208 Airport Drive
Middletown, PA 17057

[2] Continental Conservation
PO Box 57
Rose Valley, PA 19086

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Commonwealth of Pennsylvania
The Department of Conservation and Natural Resources
Rachel Carson State Office Building
PO Box 8767
400 Market Street
Harrisburg, PA 17105

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Executive Summary

The Goat Hill Wild Plant Sanctuary is a 602-acre tract of land located in the southwestern corner of Chester County and administered by the Pennsylvania Department of Conservation and Natural Resources, Bureau of Forestry (DCNR-BOF) to protect, restore, and sustain the portion of the Goat Hill serpentine barrens contained within its borders. It includes 453 acres of serpentine barrens vegetation and 149 acres of adjacent forestland, part of the 1,300-acre Goat Hill serpentine barrens conservation site, altogether encompassing 670 acres of serpentine barrens vegetation and approximately 630 acres of forested and cultivated buffer land. Goat Hill barrens, along with five other sites that make up the State Line Serpentine Barrens, is an ecologically unique system that supports the globally (G2) and state (S2) imperiled eastern serpentine barren community (NatureServe 2007). Goat Hill provides habitat for 15 animal species and 20 plant species of special conservation concern in Pennsylvania, including several species classified as threatened and endangered. Three plants that occur at the site, serpentine aster (*Symphyotrichum depauperatum*), long-haired barrens chickweed (*Cerastium velutinum* var. *villosissimum*), and glade spurge (*Euphorbia purpurea*), are globally rare. The serpentine barrens vegetation consists mainly of pitch pine - post oak - blackjack oak forest and woodland (at least 650 acres) and eastern serpentine grassland and savanna (less than 20 acres). Nearly all of the rare species live mainly or exclusively in the serpentine grassland and savanna. However, several factors including fire exclusion, soil development, forest succession, and native and exotic species invasion have severely reduced the historical extent of grassland and savanna, thus necessitating restoration. Prior to 2003, no management program was in place within the DCNR-BOF tract at Goat Hill due to its designation as a State Forest Natural Area; restoration and management on a portion of the serpentine barrens within the 147 acres owned or under easement by The Nature Conservancy at Goat Hill have been underway since 1998. In 2003, Commonwealth lands at Goat Hill were redesignated as a Public Wild Plant Sanctuary, allowing DCNR-BOF to conduct active management to restore and maintain the area in its desired natural state. The purpose of this management plan is to provide guidance to DCNR-BOF for the restoration and management of a healthy serpentine barrens ecosystem at Goat Hill. To start, restoration efforts will be directed at maintaining and expanding current grassland openings and identifying new grassland areas for restoration. The restoration of adjacent savannas will also be undertaken, while maintaining or enhancing the habitats and host species required by other rare species. The overall goal for the Goat Hill serpentine barrens conservation site is to maintain a suite of habitats that restores and sustains the long-term integrity of the serpentine barrens ecosystem, including the imperiled species of flora and fauna.

Introduction

Goat Hill barrens are an approximately 670-acre area of remnant serpentine barrens in the southwestern corner of Chester County. The Pennsylvania Department of Conservation and Natural Resources-Bureau of Forestry (DCNR-BOF) administers a 602-acre tract at Goat Hill as part of the William Penn State Forest, including about two-thirds of the area of serpentine vegetation and nearly 150 acres of adjacent oak-dominated forest (see Fig. 1). Goat Hill is located along the eastern edge of the Piedmont physiographic province and exhibits a topography characteristic of the Piedmont — sloping uplands that form long saddles and rounded hilltops, dissected by small stream valleys. The vegetation pattern in part reflects the topographic features. The concave lower hillsides and valleys are mainly associated with woodland and forest communities whereas small grasslands and savannas (scattered trees with grass-dominated understory) occur on some of the convex upper hillsides and hilltops.

Soil conditions play an important role in the patchy, mosaic pattern of vegetation present at Goat Hill. The serpentine soils of Goat Hill and the other State Line Serpentine Barrens are derived from serpentinite bedrock where the soil tends to be shallow, is highly erodible, and exhibits a "serpentine signature" soil chemistry: high in magnesium, chromium, and nickel and exceptionally low in calcium (Whittaker 1954). These soils support the characteristic scrubby, open serpentine vegetation. The shallowest, organically poorest soils occur on the rounded hilltops and are usually occupied by specialized plant species that can tolerate these conditions. Short, native, warm-season grasses such as little bluestem (*Schizachyrium scoparium*), prairie dropseed (*Sporobolus heterolepis*), and arrow-feather three-awn (*Aristida purpurascens*) dominate the grasslands on the shallowest soils. Somewhat deeper soils may support stands of taller warm-season grasses, Indian grass (*Sorghastrum nutans*) or big bluestem (*Andropogon gerardii*). Grassland areas also harbor remnant populations of rare plant species including Small's ragwort (*Packera anonyma*), annual fimbry (*Fimbristylis annua*), round-leaved fame-flower (*Phemeranthus teretifolius*), few-flowered nutrush (*Scleria pauciflora*), and serpentine aster (*Symphyotrichum depauperatum*). Scattered dwarf or stunted small shrubs are also an important component of the serpentine grassland community, including dwarf chinkapin oak (*Quercus prinoides*), New Jersey tea (*Ceanothus americanus*), pasture rose (*Rosa carolina*), low juneberry (*Amelanchier stolonifera*), and creeping St. Andrew's-cross (*Hypericum stragulum*). The eastern serpentine grassland community at Goat Hill is listed as a globally (G2) and state (S2) imperiled community (NatureServe 2008).

The soils in the woodland and forested areas are deeper and have higher organic matter content than on the upper slopes and hilltops. This is partly because trees, shrubs, and greenbrier contribute large quantities of organic matter to the soil in the form of shed leaves, bark, and dead wood. Another contributing factor is that soil accumulation rates are higher and erosion rates lower on concave slopes and in stream valleys compared with little or no accumulation and higher rates of erosion on convex slopes and hilltops. These areas are generally dominated by pitch pine (*Pinus rigida*), eastern red-cedar

(*Juniperus virginiana*), blackjack oak (*Quercus marilandica*), post oak (*Quercus stellata*), and a thick understory of greenbrier (*Smilax rotundifolia* and *S. glauca*).

Many other species in addition to threatened and endangered plants utilize the mosaic of habitats at Goat Hill. Several guilds of Lepidoptera use the grasslands and surrounding communities including 14 moth species of special concern (Smith and Johnson 2005). Rough green snakes (*Opheodrys aestivus*), a state-endangered species, have been found in the greenbrier surrounding open grasslands and other areas at Goat Hill (C. Eichelberger, personal communication). Many birds associated with native grassland-woodland edges, shrublands, and conifer woodlands/forests use Goat Hill. Because these habitat types have declined and are scarce in the region due to development and forest succession, Goat Hill is designated as an Important Bird Area (Pennsylvania Audubon 2008).

The current mosaic pattern of vegetation at Goat Hill is only a remnant of what had historically been more expansive serpentine grasslands and savannas. Exclusion of disturbance, mostly fire suppression, has allowed woody plant colonization that in turn has altered the physical characteristics of the barrens. Litter accumulation from woody species that in the past would have been consumed by fire has resulted in soil changes such as increases in soil depth, soil moisture retention, organic matter content, and available soil nutrients (Barton and Wallenstein 1997; Arabas 2000; Cumming and Kelly 2007), as well as shading, cooling, and increased humidity at ground level. These changes are self-reinforcing; they contribute to the invasion of grasslands by greenbrier and forest trees, which in turn result in further soil development and shading. Fire and grazing also once controlled greenbrier but now it dominates the woodland/forest understory and encroaches into the grasslands (Tyndall 1992). Management efforts that mimic historical disturbance regimes are necessary to maintain, expand, and restore the serpentine grassland and savanna communities at Goat Hill.

Purpose of Management Plan

The purpose of this plan is to provide guidance to DCNR-BOF for the restoration and management of a healthy serpentine community at Goat Hill. The overall goal for the Goat Hill serpentine barrens conservation site is to maintain a suite of habitats that restores and sustains the long-term integrity of the serpentine barrens ecosystem, including the imperiled species of flora and fauna and a diversity of serpentine barrens communities.

Background

Goat Hill, along with the other sites that make up the State Line Serpentine Barrens, has a longstanding history of disturbance that has helped maintain the signature soil characteristics and vegetation of the serpentine communities. Prior to European settlement, Native Americans used fire in the barrens and in large areas of the surrounding region to improve game habitat, ease of hunting, ease and security of travel, and productivity of fire-associated useful plants (Marye 1955; Tyndall 1992). Periodic

burning consumed accumulated organic matter and maintained open grasslands and savannas. Fire also controlled woody plant succession. European settlers continued this pattern of disturbance, clearing suitable areas for farming and using fire and logging to promote open areas for livestock grazing. Another shorter-lived form of disturbance, mining for chromium and magnesite, began in the 1820s, continued into the 1880s, and was briefly revived for a few years ending in 1921 (Pearre and Heyl 1960). Accidental and arson wildfires were, and still are, frequent in the barrens but have been effectively suppressed (extinguished before they cover more than a trivial acreage) since the early 1960s.

The specifics of the historical disturbance regime and the length of time that the serpentine barrens have been in existence are unknown, and probably unknowable, but we can make educated guesses based on several lines of evidence. In the mid-Atlantic region, there is evidence for widespread burning by Native Americans for at least the last 9,000 years and perhaps longer (Robinson et al. 2005). Within a few miles to the west and southwest of Goat Hill, an area of as much as a quarter-million acres in Maryland and Pennsylvania was nearly treeless at the time of first European contact (Marye 1955), indicating repeated fires over a long period of time, exceptionally severe fires during drought, or both. Few historical accounts in the region mention Indian burning frequency but a report in 1758 from east-central Pennsylvania by a representative of the colonial government, presumably from Native American informants, stated that they burned there every three to four years (Coates 1906). However, the fire return interval (average time between fires at a given point on the landscape) may have been considerably longer than the burning frequency because the total area burned in any one year would have been a fraction of the total area under management by burning in the long term.

It is likely that occasional severe fires during droughts were at least as important to the origin and maintenance of serpentine grasslands as more frequent, low-intensity fires. Ordinarily the high moisture content of the duff, or humus layer, renders it virtually fireproof. Prolonged drought thoroughly dries the duff, which becomes highly flammable. When ignited by a passing fire in grass or leaf litter, the duff may smolder for days until most of the carbon is oxidized to CO_2 and most of its mass is thus converted to smoke. This process was replicated experimentally in 1997 at the Nottingham serpentine barrens, where three replicate 30-foot by 100-foot plots of pitch pine-greenbrier forest were clearcut and covered by plastic greenhouse roofs for two months to simulate drought. Near the end of the growing season, the roofs were disassembled, the dried slash from the cut trees was spread into the plots, and the slash and dense greenbrier cover were ignited. Extremely hot fires and prolonged smoldering reduced the duff by an estimated 50 to 65 tons per acre (R. Latham and J. Thorne, unpublished data). Greenbrier mortality was nearly complete, in strong contrast to parallel treatments of mowing, low-intensity burning, moderate-intensity burning, and two years' goat browsing, all of which were followed by greenbrier recovery to nearly 100% cover within one to three years. After the drought simulation and high-severity burn, a high diversity of native grassland species established from naturally dispersed seed and became the dominant cover in the first growing season (R. Latham and J. Thorne, unpublished data).

In the absence of disturbance, Goat Hill has succeeded to a forested mosaic pattern with only a few, reduced patches of grassland/savanna remaining (see Fig. 1). This overall shift from open grassland to closed woody vegetation types is characteristic of other eastern serpentine barrens sites as well (Latham 1992; Tyndall 1992; Barton and Wallenstein 1997; Arabas 2000). Grassland/savanna patches at Goat Hill have been reduced in size due to encroachment by woody vegetation, primarily pitch pine, eastern red-cedar, and greenbrier. Frequent fires once kept the growth of greenbrier in check, but it now casts dense shade over much of the area formerly occupied by grassland, greatly reducing or eliminating the now-depauperate herbaceous layer. Invasive species such as autumn-olive (*Elaeagnus umbellata*), black locust (*Robinia pseudoacacia*), tree-of-heaven (*Ailanthus altissima*), multiflora rose (*Rosa multiflora*), Japanese honeysuckle (*Lonicera japonica*), and Japanese stiltgrass (*Microstegium vimineum*) are spreading into forested areas and along grassland edges.

Although portions of the Goat Hill serpentine barrens have been degraded by the exclusion of disturbance (mostly fire) and the encroachment of greenbrier and other woody vegetation, high-diversity open grasslands still persist in small, scattered patches. Other, open woodland areas that still have at least a depauperate herbaceous ground layer are potential sites for grassland restoration. Since Goat Hill has been redesignated from a Natural Area to a Public Wild Plant Sanctuary, an active management program can now be implemented. Since 1998, The Nature Conservancy (TNC) has been conducting restoration efforts on portions of the 147 acres under TNC ownership or easement at Goat Hill. In addition, many successful volunteer-based restoration projects have occurred at other serpentine areas in Pennsylvania and Maryland, by staff and volunteers of TNC, Maryland Department of Natural Resources, Natural Lands Trust, Lancaster County Conservancy, Tyler Arboretum, and the Chester County Department of Parks and Recreation. Insight from these projects, along with guidelines laid out by TNC in the recent report "Management Guidelines for Barrens Communities in Pennsylvania" (Orndorff and Patten 2007) were used to help develop this restoration and management plan for Goat Hill.

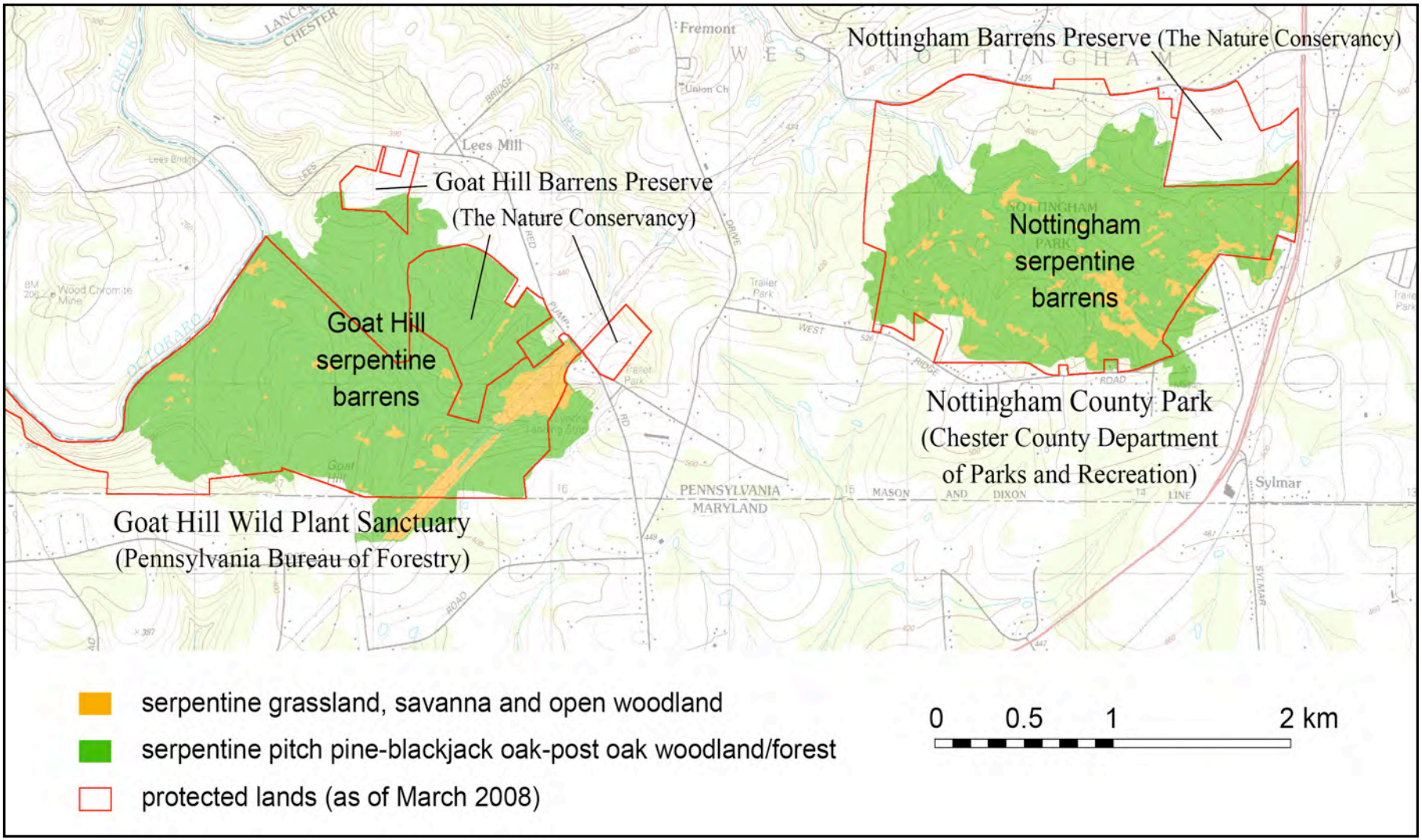

Figure 1. Map of Goat Hill serpentine barrens and nearby Nottingham serpentine barrens, showing the boundaries of tracts protected by the Pennsylvania Bureau of Forestry, Chester County Department of Parks and Recreation, and The Nature Conservancy. Mapping of the two broad serpentine plant community categories is adapted from Podniesinski (1999).

Property Description

Location

Goat Hill is located in the southwestern corner of Chester County. It is part of the State Line Serpentine Barrens running along the Mason-Dixon line in Chester and Lancaster counties in Pennsylvania and Cecil County in Maryland. The Pennsylvania Department of Conservation and Natural Resources-Bureau of Forestry (DCNR-BOF) owns 602 acres (453 acres of serpentine barrens vegetation and 149 acres of adjacent forestland); The Nature Conservancy (TNC) owns 132 acres, of which six acres are in serpentine barrens cover, and holds a 15-acre easement. Goat Hill lies less than one mile west-southwest of Nottingham serpentine barrens (see Fig. 1). The distance between them is the smallest of any two eastern serpentine barren sites, less than two-thirds of the width of either the Goat Hill or Nottingham serpentine barren areas themselves. Although it has not yet been investigated experimentally, it is likely that Goat Hill and Nottingham exchange individuals of rare animal and plant populations more often than such linkage occurs between populations at any other two eastern serpentine barren sites. For conservation biology purposes, they should be regarded as a single large site.

Goat Hill is located in a rural landscape used primarily for farming and pastureland, although pockets of residential development are present and increasing. Extensive woodlands and forests are also a major feature surrounding the site. Octoraro Creek makes up the north/northwest border while the Pennsylvania state line delineates the southern end. Red Pump Road defines the eastern side. A powerline right-of-way runs through the eastern portion of Goat Hill and the western border is adjacent to Camp Horseshoe (which includes a small, depauperate barrens remnant).

Current Land Use

At present, Goat Hill is designated as a Public Wild Plant Sanctuary. Several paths exist and are used for hiking, botanical walks, and birding. Currently, no timber harvest occurs and no burning program exists. Unfortunately, there is evidence of all-terrain vehicle use and illegal dumping — both of which have been ongoing problems for several decades.

Plant Community Types

Classification of the major natural plant communities at Goat Hill (presented below) was adapted from of a vegetation map of the State Line Serpentine Barrens derived from March 1995, false CIR aerial photography at 1:12000 scale (Podniesinski 1999; Orndorff and Patten 2007; see Fig. 1). Eight serpentine community types are recognized as a result of analysis of relevé data using ordination (detrended correspondence analysis, or DCA) and classification (TWINSPAN) techniques (Podniesinski 1999; Orndorff and Patten 2007). Each community type is crosswalked to the current Pennsylvania plant community classification (Fike 1999), the original Pennsylvania plant community classification (Smith 1991), and the National Vegetation Classification. Forested non-serpentine plant communities were also crosswalked to Society of American Foresters

forest types. The species lists represent common and characteristic species found in each community type and are not exhaustive.

Forest Communities

Red Maple - Oak - Catbrier Forest (ROC)
(*Acer rubrum* - *Quercus* spp. - *Smilax* spp.)

Typically occurs on upper slopes and interfluves with a southerly aspect. Soils are typically silt loams, greater than 30 cm deep. Forest canopy is dominated by red maple (*Acer rubrum*) and several species of oak, especially white oak (*Quercus alba*). Other common canopy species include southern red oak (*Quercus falcata*), northern red oak (*Quercus rubra*), and black oak (*Quercus velutina*). The subcanopy is characterized by red maple, white oak, black gum (*Nyssa sylvatica*), and black cherry (*Prunus serotina*). The shrub layer is dominated by lowbush blueberry (*Vaccinium pallidum*), red maple, sassafras (*Sassafras albidum*), blackjack oak (*Quercus marilandica*), blackberry (*Rubus alleghaniensis*), black huckleberry (*Gaylussacia baccata*), black cherry, and greenbriers (*Smilax rotundifolia, S. glauca*). The herbaceous layer is depauperate and typically includes the invasive Japanese stiltgrass (*Microstegium vimineum*). Other typical herbaceous species include poverty-oatgrass (*Danthonia spicata*), blue sedge (*Carex glaucodea*), and Japanese honeysuckle (*Lonicera japonica*).

[Crosswalk: Pennsylvania classification Serpentine Pitch Pine - Oak Forest (in part) and Serpentine Virginia Pine - Oak Forest (in part), Smith's Eastern Serpentine Barren (in part), NVC "*Quercus stellata* - *Quercus marilandica* Forest Alliance," "*Quercus alba* - *Quercus* (*falcata*, *stellata*) Forest Alliance"]

Red Maple - Pine - Stiltgrass - Catbrier Forest (RPSC)
(*Acer rubrum* - *Pinus virginiana*/*P. rigida* - *Microstegium vimineum* - *Smilax* spp.)

Found at mid- to low slope positions characterized by somewhat moist to moist soils. Soil texture is typically silt loam or occasionally clay loam. Soil depth typically exceeds 50 cm. Slope aspect is highly variable. Dominant canopy trees include red maple, Virginia pine (*Pinus virginiana*), pitch pine (*P. rigida*), and eastern red-cedar. The subcanopy is dominated by red maple. The shrub layer is characterized by spicebush (*Lindera benzoin*) and red maple. The herbaceous layer is dominated by stiltgrass, greenbriers, and Japanese honeysuckle.

[Crosswalk: Pennsylvania classification "Serpentine Pitch Pine - Oak Forest" (in part) and "Serpentine Virginia Pine - Oak Forest" (in part), Smith's "Eastern Serpentine Barren" (in part), NVC "*Pinus virginiana* - *Quercus* (*alba*, *stellata*, *falcata*, *velutina*) Forest Alliance," "*Pinus virginiana* Successional Forest"]

Pine - Oak - Catbrier Forest (POC)
(*Pinus rigida/virginiana* - *Quercus stellata* - *Q. marilandica* - *Smilax* spp.)

Occurs on upper slopes and ridgetops with variable slopes (0 - 10°) and a west, northwest or north aspect. Soils are somewhat moist to dry silt loams or clay loams. Soils also vary from stone-free to stony. Soil depth is not well quantified but is typically greater than 15 cm.

Dominant canopy species are pitch pine, Virginia pine, post oak (*Quercus stellata*), and blackjack oak. Pitch pine is the predominant pine at Goat Hill, with Virginia pine of minor importance or absent. The subcanopy and tall shrub layer are often sparse and are characterized by occasional individuals of black cherry, dwarf chinquapin oak (*Quercus prinoides*), blackjack oak, post oak, and red maple. The low shrub layer is more diverse and may contain black huckleberry, lowbush blueberry, sassafras, dwarf chinquapin oak, pinxster azalea (*Rhododendron periclymenoides*), black cherry, and greenbrier, mainly *Smilax rotundifolia* and, to a lesser extent, *S. glauca*. Characteristic species in the herbaceous layer are stiltgrass, forked panic-grass (*Dichanthelium dichotomum*), poverty-oatgrass, and bracken fern (*Pteridium aquilinum*).

[Crosswalk: Pennsylvania classification "Serpentine Pitch Pine - Oak Forest" (in part) and "Serpentine Virginia Pine - Oak Forest" (in part), Smith's "Eastern Serpentine Barren" (in part), NVC "*Pinus virginiana / Quercus marilandica* Forest," "*Pinus virginiana* - *Quercus* (*alba*, *stellata*, *falcata*, *velutina*) Forest Alliance"]

Woodland Communities

Conifer Woodlands (CW)

Typically occurs on steep (> 5°) north-facing high and mid-hillside slopes. Soils range from somewhat moist to very dry stony silt loams and stony sandy loams. Soil depth is typically 13 cm or less (occasionally as deep as 28 cm).

Dominant woody plants include scattered mature and juvenile pitch pine and eastern red-cedar. A few hardwood species may also occur, either as saplings or mature trees, including sassafras, blackjack oak, black cherry, and post oak. Total tree cover is typically less than 40%. The herbaceous layer has some similarity to the Little Bluestem - Prairie Dropseed Grassland community, with prairie dropseed (*Sporobolus heterolepis*) and little bluestem (*Schizachyrium scoparium*) dominant. However, greenbrier (*Smilax rotundifolia*) can be a co-dominant in some woodlands. Other important herbaceous species include Small's ragwort (*Packera anonyma*), barrens chickweed (*Cerastium velutinum*), small-leaved white snakeroot (*Ageratina aromatica* var. *aromatica*), and big bluestem (*Andropogon gerardii*).

[Crosswalk: Pennsylvania classification "Red-cedar - Pine Serpentine Shrubland" (in part), Smith's "Eastern Serpentine Barren," NVC "*Pinus virginiana* Woodland Alliance," "*Pinus rigida* - *Schizachyrium scoparium* - *Scleria pauciflora* Wooded Herbaceous Vegetation," and "*Juniperus virginiana* Woodland Alliance"]

Emergent Communities

Indian-grass - Little Bluestem Grassland (G)
(*Sorghastrum nutans - Schizachyrium scoparium*)

Occurs over shallow (15 - 25 cm deep) silt loam to clay loam soils, often at low to mid-slope positions with a north aspect. The dominant species in this grassland community are Indian-grass and little bluestem. The only important woody species is shrubby eastern red-cedar that may reach up to 40% cover in some grasslands. Other characteristic herbaceous species include serpentine aster (*Symphyotrichum depauperatum*), New York ironweed (*Vernonia noveboracensis*), yarrow (*Achillea millefolium*), tufted hairgrass (*Deschampsia cespitosa*), Small's ragwort, northern sundrops (*Oenothera fruticosa* ssp. *glauca*), arrow-feather three-awn (*Aristida purpurascens*), slim-spike three-awn (*A. longespica*), and knotroot foxtail (*Setaria parviflora*).

[Crosswalk: Pennsylvania classification "Serpentine grassland," Smith's "Eastern Serpentine Barren," NVC "*Schizachyrium scoparium - Sorghastrum nutans* Herbaceous Alliance"]

Little Bluestem - Prairie Dropseed Grassland (G)
(*Schizachyrium scoparium - Sporobolus heterolepis*)

Typically occurs on mid- to upper slopes on very shallow (usually 0 - 10 cm), stony or gravelly sand or silt loams. Exposed bedrock and bare ground are common at some locations (see gravel barrens subtype below). Soils are typically very dry, reflecting well-drained to excessively well-drained soil conditions and shallow depth to bedrock. Slope aspect is variable but is rarely due east. The slope angle ranges from 1° - 16°, and is most often between 3° - 6°.

Dominant species are grasses, little bluestem and prairie dropseed. Other characteristic species include serpentine aster, Carolina-whipgrass (*Scleria pauciflora*), barrens chickweed, gray goldenrod (*Solidago nemoralis*), Small's ragwort, Scribner's panic-grass (*Dichanthelium oligosanthes*), round-fruited panic-grass (*D. sphaerocarpon*), arrow-feather three-awn, slim-spike three-awn, and lyre-leaved rock-cress (*Arabis lyrata*). Woody plants are rare and usually are small eastern red-cedar or pitch pine seedlings and saplings.

[Crosswalk: Pennsylvania classification "Serpentine Grassland, Smith's "Eastern Serpentine Barren," NVC "*Schizachyrium scoparium - Sporobolus* (*compositus*, *heterolepis*, *junceus*) Herbaceous Alliance"]

Little Bluestem - Prairie Dropseed Grassland: Gravel Barrens Subtype (G)

Treated as a subtype of Little Bluestem - Prairie Dropseed Grassland as it is nearly identical in species composition with a few additions, including round-leaved fame-

flower (*Phemeranthus teretifolius*), rock sandwort (*Minuartia michauxii*), slender knotweed (*Polygonum tenue*), churchmouse three-awn (*Aristida dichotoma*), slender crabgrass (*Digitaria filiformis*), and poverty grass (*Sporobolus vaginiflorus*), but differs in total vegetation cover. Gravel barrens grasslands typically have less than 60% plant cover (often much less) with exposed serpentine bedrock and gravel as the remaining ground cover. In contrast to the main type, gravel barrens are more likely to occur at mid-slope positions with a steep slope (typically > 6° and as much as 16°). Gravel barrens are also more likely to have a southern aspect than the main type. Maximum soil depth is less than 10 cm with soil often restricted to isolated pockets in bedrock cracks or shallow depressions along slopes. Soils are typically very dry and excessively well-drained.

[Crosswalk: Pennsylvania classification 'Serpentine Gravel Forb Community," Smith's "Eastern Serpentine Barren," NVC "*Cerastium arvense* Sparsely Vegetated Alliance"]

Serpentine Emergent Wetland (EM)

This community occurs in groundwater seep areas of low slope (1° - 3°) and variable aspect. Soils are typically very wet (saturated) clay loams, clays, and sapric peats (muck). Soil depth is generally greater than 30 cm and can exceed 60 cm.

This community is very open with woody plants limited to occasional trees along the wetland edge and scattered smooth alder (*Alnus serrulata*) and meadowsweet (*Spiraea latifolia*) within the wetland. The dominant herbaceous species is tufted hairgrass (*Deschampsia cespitosa*). Other important herbaceous species include rice cutgrass (*Leersia oryzoides*), Indian-grass, New York ironweed, deer-tongue (*Dichanthelium clandestinum*), swamp thistle (*Cirsium muticum*), royal fern (*Osmunda regalis*), and American burnet (*Sanguisorba canadensis*).

[Crosswalk: Pennsylvania classification "Serpentine Seepage Wetland," Smith's "Eastern Serpentine Barren," NVC "*Deschampsia cespitosa* Saturated Herbaceous Alliance"]

Invasive Species

The following invasive species have been noted at Goat Hill: autumn-olive (*Elaeagnus umbellata*), black locust (*Robinia pseudoacacia*), tree-of-heaven (*Ailanthus altissima*), multiflora rose (*Rosa multiflora*), Japanese honeysuckle, and Japanese stiltgrass. Their control and eradication is addressed as a management objective.

Management Guidelines

This section provides management goals and action steps to help guide DCNR-BOF in the restoration and management of a healthy serpentine system at Goat Hill. The overall objective for Goat Hill is to promote the long-term integrity of the serpentine barrens ecosystem and maintain a suite of habitats that benefit threatened and endangered species of flora and fauna by restoring and sustaining the serpentine plant communities. Eight

community types are present at Goat Hill (see Plant Community Types section), however, not all communities will be targeted for restoration. Immediate management efforts will be directed at maintaining and expanding current grassland openings and identifying potential new grassland and savanna areas and restoring them. Surveys for rare and invasive species should include all communities within Goat Hill. The intent of this plan is that it be adaptive in nature and should be reviewed and updated at least every five years. The following goals were adapted for this management plan from the recent TNC report "Management Guidelines for Barrens Communities in Pennsylvania" (Orndorff and Patten 2007).

Management Goal #1: Maintain existing grassland openings.

Management considerations:

Sites 1 - 8 have been identified as remnant grasslands that can be expanded beyond their current boundaries to increase grassland area (see Fig. 2). These areas are small, open patches dominated by native grasses. The borders between grasslands and woodlands tend to be ill-defined, consisting of a mix of grasses and woodland species such as pitch pine, eastern red-cedar, and greenbrier. In some patches, this blurred ecotone resembles a savanna with grassland species growing under scattered trees. Prior to greenbrier removal, the greenbrier areas targeted for treatment should be thoroughly searched for rough green snakes following established protocol (see Appendix A) after permission is received from Chris Urban, Chief of the Pennsylvania Fish and Boat Commission's Natural Diversity Section. If found, snakes should be relocated to other, similar habitat at Goat Hill where they will not be inadvertently affected by vegetation removal efforts.

Management actions:

1. Compare the 1937 and 1940 aerial photo images to the most current aerial photographs to identify the locations and extent of historical grasslands relative to the present-day edges of the remnant grassland openings.

2. Increase the size of current grassland patches by removing trees from the woodland edge to extend the grassland border.

3. Remove greenbrier from the grassland/woodland border. It is important to halt greenbrier encroachment into the grasslands but it may be difficult to control. Methods used for greenbrier removal at other serpentine areas may not be feasible here due to conflicting habitat use by rough green snakes (see Management Goal #8 and Appendix A). The following list of potential greenbrier control methods have been used with varying degrees of success at other serpentine barrens areas:

    a. If the overstory is removed and greenbriers are cut back to the ground by brush-hogging, changes in light and moisture may adversely affect regrowth and some dieback may occur. However, this is likely to be only a short-term response affecting a small fraction of the greenbrier cover.

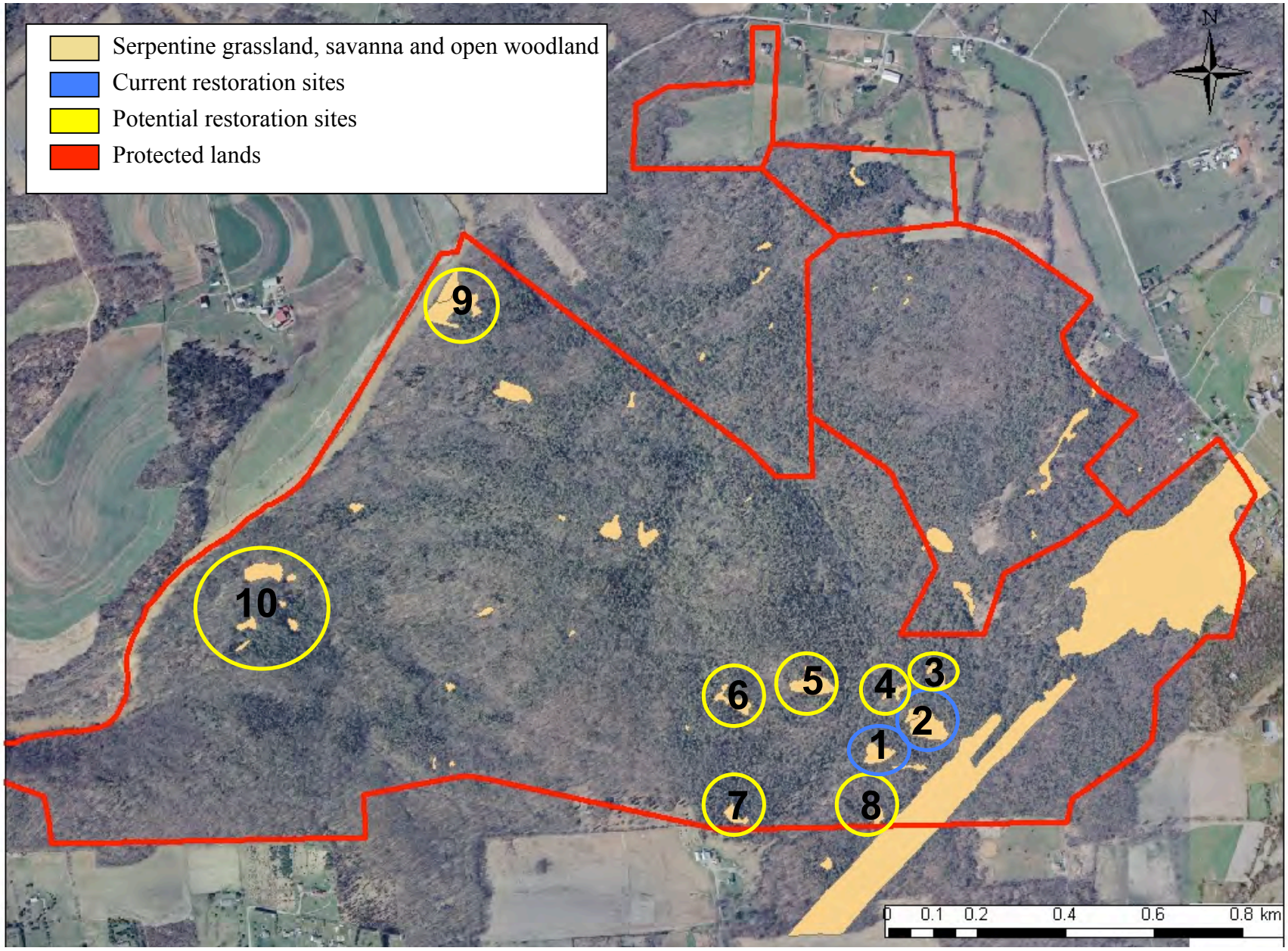

Figure 2. Map of Goat Hill serpentine barrens showing areas where restoration activities have begun (Sites 1 and 2) and areas targeted for potential restoration activities (Sites 3-10).

b. Repeated mowing may result in reduced regrowth due to loss of stored carbon but this may also be a short-term response. There is potential for regrowth if rhizomes are not removed.

c. Repeated hand pulling of aboveground biomass and rhizomes along with cutting has been effective at some sites (M. Bertram, personal communication), but due to the intensive labor required, this is practical only in small areas, perhaps no larger than ¼ to ½ acre.

d. Most rhizome establishment of greenbrier occurs in the humus layer. Removal of the humus layer along with greenbrier rhizomes, with disposal off-site, has been demonstrated to be an effective grassland restoration method at several serpentine barrens sites, with or without seed-bank augmentation

e. When a burn program is implemented, ecotonal burns may help reduce greenbrier encroachment by killing rhizomes and removing accumulated litter. Burning across the grassland-forest ecotone requires placing firebreaks in the forest well beyond the grassland edge and burning the grassland and forest edge together. Efforts should be made to maximize fire intensity at the ecotone itself, for instance, by running head fires or flanking fires into the forest edge from the grass side, where winds and other conditions make it feasible to do this safely. The effectiveness of this method will depend on site conditions.

4. Examine revegetation success after expanding patch borders. If sunlight in the newly expanded area is sufficient, revegetation by grasses should occur naturally. Grassland restoration experiments at Nottingham barrens resulted in high rates of establishment of the native serpentine grassland herbaceous flora with high species richness, indicating that reseeding occurred from nearby, intact grassland patches or a persistent seed bank, or both. If revegetation does not occur spontaneously, conduct short-interval burns (2 - 3 years) to remove accumulated organic matter. Prescribed burning at these sites should be applied only during the summer months to avoid damage to rough green snake hibernacula (see Management Goal #8 and Appendix A). If this method fails or is not an option, reduce soil organic matter by removing the humus layer for off-site disposal. If soil organic matter removal is necessary, it should be done only in the summer months to avoid damage to rough green snake hibernacula (see Management Goal #8 and Appendix A).

5. In the savanna areas where scattered trees are present, selectively remove some of the trees to maintain a sparse overstory. In savanna restoration, select trees for removal so that no two trees' leaf canopies are touching and all parts of the ground surface are exposed to direct sunlight for at least part of each day during the growing season. Either flush-cut stumps even with the ground surface level or

excavate the root crowns, whichever is most expedient for individual trees to be removed.

6. Develop a prescription burn plan to maintain serpentine grassland vegetation permanently.

7. Remove and control invasive species (see Management Goal #5). In the two sites where work has already begun, multiflora rose and Japanese honeysuckle are present in very small amounts. Japanese stiltgrass is also present along the stream bank downhill from Site 1 but the likelihood of invasion into the adjacent grassland is very low.

8. Remove all tree boles, branches, and brush from restored sites. Brush piles contribute to the accumulation of organic matter, detract from the aesthetics of the site, occupy potential habitat, and create a potential fire hazard. Woody debris can be burned on-site or used as fuel for prescribed burns.

9. Implement a monitoring program that can be used to gauge restoration success and aid in formulating adaptive management strategies.

Work has already begun in Sites 1 and 2 (see Fig. 2). In Site 1, a 4-m to 5-m border of trees has been removed to extend the perimeter of the grassland patch. Some greenbrier has been cut but more work should be done to clear greenbrier back to or beyond the new edge. Permanent monitoring plots have been established in Sites 1 and 2. Baseline vegetation data were gathered before work had begun on these sites (see Appendices B and C).

Management Goal #2: Identify new grassland sites for restoration.

Management considerations:

Using 2005 aerial photography, Sites 3 - 10 have been identified as possible areas for grassland restoration and expansion (see Fig. 2). Further ground-truthing efforts should be conducted to explore the feasibility of restoration at these sites. It has been suggested that Sites 3 and 4 should be considered for priority restoration due to their accessibility. Sites 6 and 7 are located on a ridge composed of a long set of serpentine grassy openings and savannas. The ridge is similar to the TNC-owned ridge and, like that site, should be managed for clearing as one contiguous unit (M. Bertram, personal communication).

Management actions:

1. Identify potential sites for restoration using aerial photography, vegetation maps (Podniesinski 1999), and topographic maps. Compare the 1937 and 1940 aerial photo images to the most current aerial photographs to identify the locations and extent of historical grasslands.

2. Once potential sites are identified, ground-truth those areas to examine site characteristics that may affect the feasibility of restoration. Some site characteristics to take into consideration are:

    a. Present species assemblages. Are any species present that represent the former grassland or that could be used as a seed source for restoration efforts? Are there small patches of grassland within the site that can be connected to form a larger contiguous area of grassland?

    b. Accessibility for restoration work. Is the area accessible by trail or will one have to be made to reach the site? Is it accessible for people or off-road utility vehicles carrying restoration-related equipment or, where needed, transporting the debris produced by tree cutting, greenbrier pulling, or soil organic matter removal? (See Management Goal #12)

    c. Soil profile. What is the soil depth? How much accumulated organic matter is present? Is scraping likely to be required to reduce the humus layer?

    d. Spatial relationship to other grasslands. Are established grassland patches close enough to connect or to serve as potential seed sources via natural dispersal mechanisms?

3. If restoration is feasible at a particular site, examine existing vegetation patterns to aid in developing an effective, site-specific approach to restoration. Existing open grassland patches can be expanded in size by removing trees and greenbrier. Dense trees in smaller size classes or of species other than pitch pine, post oak, and blackjack oak can be clearcut to achieve open grasslands. Areas containing mature pitch pines, post oaks, and blackjack oaks may be thinned to re-create serpentine savannas.

Management Goal #3: Restore the natural diversity of serpentine species, vegetation structure, patch variation, and community types.

Management considerations:

The next step after existing grasslands have been expanded and the tree canopy removed or thinned at new restoration sites is to encourage a diverse growth of serpentine-adapted species on these sites. Natural variation in soil characteristics and other environmental conditions within the serpentine barrens as a whole influence vegetation patterns, including the distribution of specific serpentine community types. Most of the native grasses and rare species are best suited for thin, gravelly soils exposed to full sunlight. Tallgrass stands, savannas, and forested areas generally have deeper, moister soils. Wet areas are suited to serpentine emergent wetlands. An important goal is to maintain a mosaic of community types while restoring and enlarging the total area dominated by grasses and other herbaceous plant species.

Management actions:

1. Delineate vegetation patterns before restoration activities begin by establishing permanent monitoring plots that will allow detailed characterization of existing vegetation (see Management Goal #4). These patterns will provide insight into soil characteristics and other key drivers of ecosystem function and will also provide baseline data for evaluating restoration efforts and management goals. Because grasslands are most stable on thin, gravelly soil with low organic matter content, greater ease and higher rates of success in converting forested areas to grasslands or savannas can be expected in those areas now in forest cover that have the least accumulated organic matter.

2. Remove trees, tall shrubs, and greenbrier from areas that will be restored to grasslands. To the degree possible, protect existing grass and sedge tussocks, other native herbaceous plants, and dwarf or stunted, native, serpentine-characteristic shrub species from damage while removing other woody vegetation.

3. Examine revegetation success after tree and brush removal. If greenbrier rhizomes are not too abundant, revegetation by native, characteristic serpentine species is likely to occur naturally and spontaneously via seed dispersal from intact grassland patches nearby and a persistent seed bank. If greenbrier comprises more than 20% of the total cover of new ground-layer growth after canopy opening, short-interval burns (2 - 3 years) can be used to weaken it, deplete the nutrient stores in its rhizomes, and favor serpentine-adapted herbaceous species. If this method fails or is not an option, use soil scraping and off-site disposal to reduce soil organic matter. If soil scraping is necessary, it should be done in the summer months to avoid damage to rough green snake hibernacula (see Management Goal #8 and Appendix A).

4. Encourage revegetation of native grasses and other serpentine species if it does not occur naturally within two years of soil restoration by sowing and lightly mulching seeds of characteristic serpentine grasses and other herbaceous species. Since little is known about genetic variability among serpentine sites, reseed only with seeds collected from grasslands within the Goat Hill serpentine barrens.

5. Areas classified as “Conifer Woodlands” and “Pine - Oak - Catbrier Forests” can be restored to savannas by selectively thinning eastern red-cedar, pitch pine, oaks, and remaining tall shrubs. Girdling some trees instead of cutting will provide habitat for cavity-nesting birds. Burning these patches as soon as ground vegetation is thick enough to carry a hot fire (1 - 3 years) will reduce accumulated organic matter and is likely to help reduce or eliminate greenbrier, so long as the tree canopy is sufficiently open that grasses can grow fast and tall enough to shade the weakened greenbrier shoots. This method was successfully used at the Nottingham serpentine barrens.

6. Remove all tree boles, branches and brush from restored sites. Brush piles contribute to the accumulation of organic matter and also detract from the aesthetics of the site, occupy potential habitat, and create a potential fire hazard. Woody debris can be burned on-site or used as fuel for controlled burns.

Management Goal #4: Develop a monitoring program.

Management considerations:

An important component of a management plan is a monitoring program. Monitoring can provide managers with an understanding of what they have before restoration efforts have begun (biological monitoring), the response to restoration actions (effectiveness monitoring), and the ability to change management actions when presented with new information (adaptive management). A monitoring program was begun for Sites 1 and 2 prior to any management action, following Natural Heritage Program methodology (see Appendices B and C). Monitoring plots were established and baseline vegetation data were collected in August 2007 (see Appendices C and D). In 2008, monitoring plots in these areas will be permanently marked and vegetation plots revisited.

Management actions:

1. For proposed restoration sites, establish permanent vegetation monitoring plots prior to restoration activities using Natural Heritage Program methodology (see Appendix B). Baseline data should include site photographs and species occurrence and abundance information. Multiple plots also should be located in nearby areas not slated for restoration but closely similar to those that will receive treatment. These plots will serve as comparison plots, allowing data analysis to separate the effects of restoration treatments from uncontrolled effects that are likely to vary at the same time as treatments, such as weather and herbivory.

2. Revisit plots or a subsample of plots periodically to monitor the impact of management techniques on plant growth and species composition. Compare data after restoration efforts to baseline data (recorded before treatments) and to untreated comparison plot data (recorded at the same time as data on treatment plots) to examine the effects of management efforts. If necessary, make changes to management actions based on these comparisons.

3. Conduct new baseline inventories for groups of species that have not yet been surveyed. For example, rough green snakes have been found at Goat Hill but no formal inventory has been conducted to provide an understanding of population dynamics.

4. Monitor Lepidoptera species and host plants. Some restoration activities may have negative effects on existing Lepidoptera species. When a burn program is implemented for vegetation control and maintenance, fire should be used in

patches and across a relatively small fraction of overall habitat in any given year to minimize collateral Lepidoptera losses (Schweitzer 1998).

5. Create a central database for all data collected that can be used to evaluate best management practices and for comparisons with other serpentine site restoration projects. This database will also be important for evaluating the management plan and aid in its update every five years.

6. Monitor the occurrence and spread of invasive species (see Management Goal #5).

Management Goal #5: Develop an invasive species management plan.

Management considerations:

Invasive plant species noted at Goat Hill are autumn-olive, black locust, tree-of-heaven, multiflora rose, Japanese honeysuckle, and Japanese stiltgrass. These species not only displace common native species by outcompeting them for resources but may also contribute to the decline and possible extirpation of species of concern. For example, Japanese stiltgrass not only dominates the streambanks below Site 1 but may also be negatively impacting glade spurge reproduction (M. Bertram, personal communication). Invasive species control and eradication is vital to the success of serpentine barrens restoration and maintenance.

Management actions:

1. Identify and map invasive hotspots. Use this information to help prioritize eradication efforts.

2. Determine which methods are best suited for the removal of specific invasives in particular situations.

3. Treat invasive species. Priority should be given to those areas that have both invasive species and species of special concern. Depending on the methods used to treat invasives, this may be a good activity for volunteers.

4. Continue to monitor both the effectiveness of treatment methods and the occurrence or reoccurrence of invasives. Take into consideration that some invasives may require multiple years of treatment before they are successfully eradicated, and others may not be practical to eradicate completely but will require permanent vigilance and management to minimize their impacts on the native communities.

5. When conducting restoration and invasive control activities, it is important to keep in mind that humans and equipment can be modes of dispersal for some

invasive species. Make every reasonable effort to minimize the spread of invasives.

Management Goal #6: Develop a management plan for threatened and endangered plants.

Management considerations:

The vegetation at Goat Hill, along with the other State Line Serpentine Barrens, represents a unique assemblage of species endemic to serpentine outcrops, native grasslands, mixed hardwoods, and oak stands. The plant species of special concern (Table 1) are for the most part confined at Goat Hill to the serpentine grasslands and savannas. The exceptions are rigid tick-trefoil, glade spurge, southern red oak, and cranefly orchid, which occur mainly in woodland or forest. Several species of concern have been found at Sites 1 and 2 (see Appendix D).

Table 1. Plant species of special concern in Pennsylvania with extant populations at Goat Hill. Three of the plants are globally rare: long-haired barrens chickweed, glade spurge, and serpentine aster.

common name	scientific name	PA status*
Richardson's sedge	*Carex richardsonii*	PE
long-haired barrens chickweed	*Cerastium velutinum* var. *villosissimum*	PE
rigid tick-trefoil	*Desmodium obtusum*	TU
annulus panic-grass	*Dichanthelium annulum*	PT
Heller's witch-grass	*Dichanthelium oligosanthes*	TU
glade spurge	*Euphorbia purpurea*	PE
sandplain wild flax	*Linum intercursum*	PE
plain ragwort	*Packera anonyma*	PR
round-leaved fameflower	*Phemeranthus teretifolius*	PT
Virginia ground-cherry	*Physalis virginiana*	PE
pink milkwort	*Polygala incarnata*	PE
southern red oak	*Quercus falcata*	PE
few-flowered nutrush	*Scleria pauciflora*	PT
prairie dropseed	*Sporobolus heterolepis*	PE
serpentine aster	*Symphyotrichum depauperatum*	PT
cranefly orchid	*Tipularia discolor*	PR

*Pennsylvania status codes:
PE — endangered in the state
PR — rare in the state
PT — threatened in the state
TU — status tentatively undetermined and under study

Management actions:

1. Conduct an inventory of threatened and endangered plants including revisits to old element occurrences to document persistence over time. Many of the old occurrences did not include GPS coordinates for site locations. Nearby Nottingham serpentine barrens, whose populations can be assumed to have been strongly linked historically with those at Goat Hill, has confirmed occurrences of 10 additional plants of special concern in Pennsylvania; some of these are likely to have inhabited Goat Hill in the past and additional searching may turn up small remnant populations. Conducting a new inventory would allow for an update of old records and collection of new information that can be used to direct management efforts. Location information on species of concern will also be useful when planning new trails (see Management Goal #12). This information should be collected in the standard format used by the Pennsylvania Natural Heritage Program.

2. Once the list of rare species is updated, identify the conservation needs of the species and how these needs can be met in the management plan. For example: round-leaved fame-flower is found in open, high light areas where soils are thin or absent. Periodic scraping (or another form of disturbance that mimics erosion) may be necessary to maintain the microenvironment suitable for this species.

3. The use of exclosures may be necessary for protection of rare plants that are declining or prevented from setting seed by deer browsing and grazing. In the past, exclosures were used to protect glade spurge. Existing and future exclosures will need to be maintained.

Management Goal #7: Develop a management plan for threatened and endangered Lepidoptera.

Management considerations:

Several guilds of Lepidoptera use the grasslands and surrounding communities including a high number of rare species. The most recent surveys are from 2004 and 2005 when 298 species of moths were documented including 14 considered as species of special concern (Smith and Johnson 2005; Orndorff and Patten 2007).

Management actions:

1. Conduct a survey of butterflies and day-flying moths to determine if rare species in these guilds are present at Goat Hill. If so, identify the conservation needs of the species and how these needs can be met in the management plan. Repeat surveys when necessary.

2. Identify the location of food plants used by the larval stage of rare Lepidoptera species. Wild indigo (*Baptisia tinctoria*) is used by frosted elfin (*Callophrys*

irus), a state-imperiled species with rank S1S2 (Pennsylvania Natural Heritage Program 2008). A geometer moth (*Apodrepanulatrix liberaria*) and the broad-lined catopyrrha (*Erastria coloraria*), ranked S3 and S1, respectively (Pennsylvania Natural Heritage Program 2008), feed on New Jersey tea (*Ceanothus americanus*) as larvae. This food plant inventory could be done in conjunction with the rare plant survey (see Management Goal #6).

3. Conduct a survey in areas containing New Jersey tea to determine if *Apodrepanulatrix liberaria* and the broad-lined catopyrrha are present at Goat Hill. If not, Schweizer (1998) suggested reintroducing rare Lepidoptera that occurred formerly at Goat Hill, using reared stock from pregnant females captured at Nottingham serpentine barrens.

4. If food plants are located, efforts should be taken to protect at least part of their populations from deer browsing using exclosures. Exclosures will need to be maintained over time.

5. Maintain grassland openings and the mosaic vegetation pattern to suit the needs of guilds represented at Goat Hill. When a burn program is implemented for vegetation control and maintenance, fire should be used in patches and across a relatively small fraction of overall habitat in any given year to minimize collateral Lepidoptera losses (Schweitzer 1998). Burn units should be small and the same unit or adjacent units should not be burned in consecutive years to allow Lepidoptera to repopulate from the unburned areas (G. Gress, personal communication).

Management Goal #8: Develop a management plan for the rough green snake.

Management considerations:

Goat Hill is one of a very few sites in Pennsylvania where rough green snakes have been documented. Although globally secure (G5), rough green snakes are listed as imperiled (S1) in Pennsylvania (Pennsylvania Natural Heritage Program 2008) because the extreme southern portion of the state is the northernmost limit of the snake's range (Hulse et al. 2001). Rough green snakes have been found in the greenbrier surrounding open grasslands and other areas within Goat Hill (C. Eichelberger, personal communication), the same areas where greenbrier is considered a nuisance because it is invading grasslands, greatly reducing diversity of, and habitat for, grassland species. Special consideration must be given to the habitat use of rough green snakes when planning restoration activities. Since little is known about the biology of rough green snakes, a conservative approach must be taken when managing potential rough green snake habitat and implementing restoration methods.

Management actions:

1. Little is known about the biology of rough green snakes. Information is insufficient to decisively guide management actions. Further research into habitat requirements and life history of the Goat Hill population is vital.

2. Since little is known about habitat use by rough green snakes, consider greenbrier patches, especially those adjacent to open areas, as potential rough green snake habitat when planning management-related activities.

3. Before beginning any activities involving greenbrier, the area must first be searched for snakes following the rough green snake monitoring protocol (see Appendix A) and the snakes relocated or shepherded away from the area to be treated.

4. Little is known about the hibernating behavior of rough green snakes but the potential presence of hibernacula should be taken into account when considering burning, scraping, and the use of heavy machinery for restoration purposes. These types of activities should be limited to late spring and summer when underground dens are not in use.

Management Goal #9: Develop a management plan for birds.

Management considerations:

Many birds associated with grassland-woodland edges, shrublands, and conifer woodlands/forests use Goat Hill. Because these habitat types have declined due to development and forest succession and are scarce in the region, Goat Hill is designated as an important Bird Area (Pennsylvania Audubon 2008).

Management actions:

1. Maintain the mosaic pattern of vegetation following Management Goals 1, 2 and 3.

2. To gain a better understanding of habitat usage by birds at Goat Hill, coordinate information sharing with the volunteer or volunteers responsible for the Pennsylvania Breeding Bird Atlas block that contains the site.

Management Goal #10: Investigate the need for a deer management plan.

Management considerations:

Deer browsing has been associated with the reduction and loss of plant species. In addition, species dependent on deer-impacted plants have also suffered population losses or have been extirpated. No current assessment of deer populations and deer damage has

been conducted at Goat Hill. A few examples of species impacted by deer browsing at Goat Hill are glade spurge, wild indigo, New Jersey tea, cranefly orchid, and Philadelphia wood lily (*Lilium philadelphicum*). Glade spurge is a globally rare species (G3 S1). The reduction or loss of wild indigo and New Jersey tea is tied to the increasing rarity or extirpation of several Lepidoptera species (Schweitzer 1998). Cranefly orchid and Philadelphia wood lily are among many native species that live at Goat Hill or in serpentine barrens that are especially vulnerable to high deer populations. Monitoring ecosystems to assay baseline deer impacts and change as deer populations are reduced is a hugely complex issue that managers typically have a hard time finding anything to rely on for guidance.

Management actions:

1. Determine what impacts the deer population at Goat Hill and is having on vegetation composition and structure by establishing a monitoring program for selected indicator species and relative plant species abundances inside and outside of deer exclosures.

2. If the deer herd is shown to be having detrimental impacts on native plant populations, rare Lepidoptera, or community structure, consider methods for population control (i.e., increase availability of antlerless deer licenses and actively promote their use among local hunters).

3. Protect sensitive plants or areas from deer, using exclosures. Rigorously inspect and maintain existing exclosures. Several exclosures were built around the glade spurge populations at Goat Hill but there is no program in place to assure their continued maintenance.

Management Goal #11: Implement outreach programs to educate local government officials, landowners, and the public on the importance, management needs, land protection, and stewardship options for Goat Hill along with encouraging public use of Goat Hill.

Management considerations:

Farmland and pockets of residential development surround Goat Hill. Some restoration activities that occur at Goat Hill could indirectly affect adjacent properties. Maintaining a good working relationship with the surrounding community and the local municipality is necessary to help build support and interest in restoration efforts.

Management actions:

1. Educate the surrounding community and local government of the ecological value of Goat Hill and why restoration activities are necessary.

2. Keep the public informed about work being done at Goat Hill, especially concerning the burn program when it is implemented. This can be done through articles in the local newspaper and announcements at meetings. Posting signs at Goat Hill that explain what restoration activities are occurring and why will serve as a means of informing and educating the public.

3. Develop a recreation program at Goat Hill. To encourage the public use of Goat Hill, focus on recreation-related projects outlined by Scott E. Rimpa (Recreation Section, Division of Operations and Recreation, Department of Conservation and Natural Resources) (Rimpa 2006, 2008).

4. Provide information kiosks or billboards about Goat Hill, the importance of serpentine communities, and current restoration efforts.

5. Develop a volunteer group or Goat Hill "friends" group to help with public education and restoration efforts. A dedicated group of volunteers are already involved with restoration activities at other State Line Serpentine Barrens and may be interested in lending their time and experience to Goat Hill.

Management Goal #12: Develop a trail system for Goat Hill.

Management considerations:

A well-developed trail system is necessary at Goat Hill not only for public use but also to help facilitate restoration-related activities including a prescribed burn program. The existing trails were created illegally and are not sustainable in their current state.

Management actions:

1. Map the existing trails across the entire area of the Goat Hill serpentine barrens. This task was begun by M. Bertram in 2004 and 2005 using GPS; his results are available as a GIS layer.

2. Develop a plan for trail rehabilitation and creation of new trails. Use the suggestions for rehabilitating trails and developing new trails as outlined by Scott E. Rimpa (Recreation Section, Division of Operations and Recreation, Department of Conservation and Natural Resources) (Rimpa 2006, 2008).

3. Examine the relationship between existing trails and proposed new trails and existing grassland patches, potential restoration areas, and known locations of rare plant species and invasive-species trouble spots. To help facilitate restoration activities (such as controlled burns) and invasive species control, it will be important to establish trails to access these areas. It is also important to avoid placing trails in areas where species of concern are found. Data collected from Management Goals 2, 5, and 6 should be incorporated into trail planning.

4. Develop a plan for eliminating illegal off-road motorized activity. Use suggestions for curtailing these activities as outlined by Scott E. Rimpa (Recreation Section, Division of Operations and Recreation, Department of Conservation and Natural Resources) (Rimpa 2006, 2008).

5. After a trail system is developed, create a detailed trail map of Goat Hill for public usage.

Action Items for 2008

In keeping with the adaptive nature of this plan, we will meet each year to review activities accomplished in the previous year and establish action items for the current year. The annual meeting will also provide an opportunity to reexamine the management plan and address potential changes. The following is a list of action items for 2008:

1. Continue work at Sites 1 and 2. In 2008, we will focus on the following tasks. First, inventory the sites. A qualitative assessment will allow us to develop a list of species present within each grassland patch. To try to capture the full extent of species occurring within these sites, it will be necessary to visit the areas several times throughout the growing season. This task will also include revisiting the monitoring plots and permanently marking them. Second, continue enlarging the perimeters of Sites 1 and 2. Last year Joe Frassetta and his team began enlarging the perimeter of Site 1. This work will continue at Site 1 and also be done at Site 2 in 2008. (Management Goal #1, Management Goal #4)

2. Examine different techniques for greenbrier control. We will use an experimental approach to examine the effects of separate and combined techniques used for greenbrier control. A tentative timeframe for this project is late summer or early fall. (Management Goal #1)

3. Assess sites for future restoration activities. In the draft management plan, Sites 3 through 8 were considered as possible sites for future restoration work. Two additional sites in the western portion of Goat Hill were noted in the management plan meeting and will be added to the final management plan. Before starting restoration activities in these areas, we need to examine the feasibility of restoration work at these sites. This assessment will probably take place throughout the field season and it may be necessary to continue this assessment into 2009. (Management Goal #2)

4. Survey for threatened and endangered species. This will involve revisiting old element occurrences to confirm their survival and gather additional information on any new element occurrences. Multiple visits to Goat Hill will be necessary to carry out this task. (Management Goal #4, Management Goal #6)

5. Survey for and develop an invasive species map for Goat Hill. It will enable us to prioritize species and specific sites for treatment. Surveys will be conducted throughout the field season. (Management Goal #5)

6. Survey for butterflies and day-flying moths. A survey has not been done lately and this would provide us with more detail on the plant needs of Lepidoptera found at Goat Hill. Surveys will be conducted in May and June for early-season species and in July and August for later-season species. (Management Goal 4, Management Goal #7)

7. Develop a trail, forest road, and firebreak map. This information will be necessary for developing trails for public use and provides us with an idea of accessibility to restoration sites. Joe Frassetta will continue working on this project. (Management Goal #12)

8. Develop information about Goat Hill for the general public. Joe Frassetta will be working on this. (Management Goal #11)

9. Develop a friends group for Goat Hill. Joe Frassetta has already begun this and will continue working on this project. (Management Goal #11)

10. Meet in early 2009 to discuss accomplishments in 2008 and outline work for 2009. The forum can be structured similarly to this year's meeting. An annual report will be written and distributed to the group before the meeting to facilitate discussion of accomplishments and planning for 2009 action items.

Research Needs

Goat Hill, along with the other State Line Serpentine Barrens, represents a small remnant of a unique ecosystem. Although some research, restoration, and management work has been done in this ecosystem, many unknowns still exist about serpentine communities and the species that use these habitats. There are also many gaps in our knowledge pertaining to the management of the serpentine barrens that can be addressed through experimentation. The following is a list of research projects that would contribute to a better understanding of serpentine barren dynamics and the development of better-informed best management practices for restoring and maintaining the ecosystem.

1. Evaluate techniques for greenbrier control. A series of experimental units can be established within several expanded or reclaimed grassland areas. Different methods of greenbrier control can be applied to each unit and evaluated to help determine best greenbrier management practices at Goat Hill across the range of conditions found there.

2. No work has been done on seed bank dynamics but it is important to examine the persistence of a seed bank in the restoration context. Does a seed bank persist in areas that were once grasslands and have succeeded into woodlands? Do grassland species differ in seed longevity? Soil samples can be taken from

various sites at different stages of succession and grown out in a greenhouse to examine seed bank dynamics.

3. Compare the effects on soils, light levels, and litter fuel quality of eastern red-cedar with those of trees native to serpentine barrens (pitch pine, blackjack oak, and post oak) and other invaders of serpentine areas (Virginia pine and red maple). Eastern red-cedar is an invader of serpentine barrens and is thought to have characteristics similar to another problematic invader, Virginia pine. However, this hypothesis has not been tested.

4. Compare the outcomes of restoration methods used at other serpentine barren sites for possible application at Goat Hill. Restoration activities done on the TNC property at Goat Hill can be repeated in some of the new areas designated as potential restoration sites and their outcomes can be compared.

5. Examine the habitat use of rough green snakes at Goat Hill. Little is known about habitat use by rough green snakes but it is important to understand this from a management standpoint since the focus of some restoration activities will be the removal of greenbrier, some of which is potential rough green snake habitat. Telemetry and capture-recapture techniques can be used to examine habitat use. It is also important to understand hibernation activities since the use of heavy machinery, scraping, and burning could damage or destroy rough green snake hibernacula.

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Appendix A. Protocol for rough green snake searches prior to restoration-related activities and summary of rough green snake surveys in 2007

Author: Charlie Eichelberger, Pennsylvania Natural Heritage Program

Acronyms used in this appendix:
DCNR: Department of Conservation and Natural Resources
BOF: Bureau of Forestry
PFBC: Pennsylvania Fish and Boat Commission
OPAE: *Opheodrys aestivus* rough green snake
ROW: right-of-way
WP: waypoint
SVL: snout-vent-length
TL: tail length
ToL: total length
ADL: adult
JUV: juvenile

General rough green snake (*Opheodrys aestivus*) ecology

The rough green snake is a widely distributed species in North America, present from as far west as Texas, throughout the southern Midwestern states, and extending from the southern most tip of Florida to the terminus in a handful of counties in southern Pennsylvania and southern New Jersey (Ernst and Ernst 2003). The species is considered apparently secure to secure in the majority of its range (NatureServe rank S4-S5), with Indiana, Ohio, and West Virginia listing the species as "vulnerable" (NatureServe rank S3).

In Pennsylvania, records exist in southeastern Pennsylvania (Lancaster and Chester Counties) and southwestern Pennsylvania (Greene County), with likely misidentifications from central Pennsylvania (Northumberland and Union Counties) and possible misidentifications from the southwestern portion of the state (Allegheny and Westmoreland Counties) (Hulse et. al 2001). The southwestern Pennsylvania population in Greene County has not been recorded since 1924, and is presumed extirpated (Hulse et. al 2001; PFBC 2005). The limited range of the species in the state has led the Herpetological Technical Committee of the Pennsylvania Biological Survey to rank the species as critically imperiled (NatureServe rank S1). Additionally, the Pennsylvania Fish and Boat Commission moved the rough green snake from the threatened list (1974) to the endangered list in 2002. The justification for this change in status was the failure to find any specimens or new populations of the species, despite a statewide effort to catalogue the ranges of the state's herptiles during the Pennsylvania Herpetological Atlas run by Dr. Art Hulse of Indiana University of Pennsylvania (PFBC 2005).

Despite the wide range of the species, concentrated ecological studies of rough green snakes have focused on the southern populations, primarily in Arkansas and Oklahoma (Goldsmith 1984; Plummer 1981; Plummer 1990), with no dedicated studies coming from Pennsylvania. Existing studies have suggested that the species is highly tied to riparian habitats, with relatively few captures more than a few meters from water (Plummer 1981; Plummer 1990; Plummer 1997). Observations away from stream habitats, even though closely associated with other water bodies, have been labeled as

"atypical habitat use" (Duellman 1949). Rough green snakes were most closely associated with "edge" type habitats in Oklahoma, however only 4% of these locations were in upland wooded areas, deviating from what has been observed in Pennsylvania (pers. obsv.). Rough green snakes in the Oklahoma study were also noted to exhibit no strong preference for any type of vegetation, with only 15% of captures in greenbrier (*Smilax* spp.) (Goldsmith 1984). Surveys conducted by the Pennsylvania Natural Heritage Program (PNHP) over the past few years have noted the affinity of rough green snakes for greenbrier habitat during the active season (pers. obsv.). Beyond the use of greenbrier, the species also requires other habitats for retreats and nesting. Dead woody debris, and cavities associated with tree roots have been documented as retreats for rough green snakes. Rotting logs were used as nesting sites in Oklahoma (Goldsmith 1984).

Previous survey work on rough green snakes in Pennsylvania found that the species is often associated with drier habitats than suggested in the studies from the south (pers. obsv.). While these studies serve as the best source for ecological information on the species, rough green snakes in Pennsylvania may have different ecological needs aside from obvious differences in habitat use. For this reason, dedicated studies on the ecology of Pennsylvania rough green snake populations are necessary for us to better manage the habitats for this state endangered species. It is important to note that rough green snake searches along the typical riparian habitats used in the southern range of the species have in large part not been conducted in Pennsylvania. Searches along riparian habitats in the Commonwealth would provide a far better picture of the ecological needs of the species in this portion of its range.

The home ranges of studied rough green snakes in Arkansas have been notably small. In Plummer's 1981 study, the snakes captured more than four times within a season had an average activity range of 62m (range 0-247m). One individual in this study was captured eight times in less than one year, with all captures within a 30m stretch of shoreline, suggesting a small home range (Plummer 1981).

Rough green snakes are noted to be nearly exclusive insectivores, primarily feeding on grasshoppers, crickets, caterpillars, spiders, odonates, and occasionally snails and frogs (Ernst and Ernst 2003, Plummer 1981).

Mating seasons for the rough green snake in Pennsylvania is unknown; however, a study in Virginia noted rough green snakes courting in mid-September (Richmond 1956) while rough green snake courtship in laboratory experiments was concentrated from May to June, with some courtship activity occurring in the fall (Goldsmith 1988). Studies indicate that rough green snakes will nest communally (Goldsmith 1984, Palmer and Braswell 1976). If this behavior also occurs in the Pennsylvania populations, identification of nesting sites is critical in order to avoid potential damage to concentrated nests of multiple individuals while conducting land management related activities.

Nesting has been documented as early as mid-June through the end of August. Nest sites have included rotting logs, beneath a rotting cardboard box, and inside the walls of an old refrigerator (Goldsmith 1984).

Demographic studies of rough green snakes have revealed that populations are roughly 1:1 males to females (Tinkle 1960). Sample sizes of sexed rough green snake captures in Pennsylvania are too small to warrant statistics relating to demography.

Predation on rough green snakes occurs from fish, birds, mammals, and other species of snake, including Black Racers (*Coluber constrictor*) which have been observed at one rough green snake site in Pennsylvania (Goldsmith 1984, Plummer 1990).

Rough green snake survey protocol for the Goat Hill Wild Plant Sanctuary (Chester County, Pennsylvania)

General search protocols for Rough Greensnakes
Surveys for rough green snakes may be conducted from May 1st, through October 15th. Daytime searches may be conducted from one hour after sunrise, to one hour before sunset. Rough green snakes in Arkansas have been found to be active soon after first light, and 0.5-1.0 hours before dark (Plummer 1981).

Searches for rough green snakes should focus on greenbrier thickets since evidence suggests the affinity for greenbrier by rough green snakes during the active season (C. Eichelberger, personal observation). The condition of greenbrier thickets dictates the amount of search effort necessary to detect rough green snakes. Areas where greenbrier foliage is taller than 0.3 m and dense (covering between 50 and 100%) will be searched for a minimum of 30 minutes per 100 m^2 for surveys in the surface of the greenbrier (the area where greenbrier foliage is concentrated), and 15 minutes of search time below the surface of the foliage mats. Areas where greenbrier is moderately dense (covering between 25 and 49%) will be searched for a minimum of 15 minutes per 100 m^2 in the surface and 15 minutes below the surface of the foliage mats. Areas where greenbrier is sparse (covering between 0 and 24%) will be searched for a minimum of 15 minutes per 100 m^2. The area and foliage density will be visually estimated to allow for continual alteration of search effort for rough green snake in this varying habitat.

Nighttime surveys will include the use of high-powered flashlights or spotlights to search the canopy and sub canopy vegetation layers. Nighttime surveys will begin approximately one hour after sundown. These searches will consist of at least five minutes per 100 m^2 where canopy trees are present. This method has been shown to be effective at locating rough green snakes in the southern portion of the species range (Plummer 1981). The effectiveness of this method has not been evaluated in Pennsylvania.

Rough green snake Methodologies for the 2007 season
All snakes captured will be marked using a medical grade cautery available from Jorgensen Laboratories, Loveland Colorado (Cautery 2200 degrees, item #J313A). Branding the scales will only take place on the scales posterior of the anal plate, at least 8 scales away from the anal plate to avoid the possibility of injuring the snake's organs, as recommended by Dr. Robert Cook (NPS). Each captured snake will receive a unique

coded mark, and data will be collected on the individuals including: weight, total length (ToL), snout-vent-length (SVL), sex, and any other notes possible regarding body condition (gravid or nongravid, scarring from previous injures etc.).

Notes will also be collected on habitat use, and may include dominant vegetation and structure, canopy cover, air and substrate temperatures, approximate distance to water, time of capture, and other pertinent data.

Searches will consist of three days of daytime searches, and at least two nights of nighttime searches before the scheduled date of management. Snakes captured will be relocated approximately 100 m from the point of capture, away from the targeted management area. Snakes located during nighttime surveys, out of the reach of surveyors, will not be moved; instead the tree will be marked so that it will not be cut. Using the cautery marking system and the translocation of snakes will provide information on the efficacy of moving rough green snakes to "safe" areas before management for serpentine barrens grasslands is conducted. Other herptiles encountered (most likely eastern box turtles, black rat snakes, and eastern garter snakes, among others) will also be moved out of the immediate targeted management area.

Management is to consist of a work crew of less than 10 individuals, using chainsaws to remove woody vegetation (primarily pitch pine and Virginia pine).

Day by day summary of rough green snake work completed during the 2007 field season at Goat Hill Wild Plant Sanctuary.

2007Jun1 – The purpose of this field day was to ground delineate the boundary of where management will take place. Two sites (Site 1 and Site 2) with good potential for restoration were delineated using aerial photography. While Greg Podniesinski and Tim Draude discussed the management approach, Charlie Eichelberger and Aura Stauffer searched the greenbrier thickets surrounding the remaining grassland patch at Site 1. The area surrounding the serpentine grassland patch appeared to be ideal OPAE habitat, and should be searched before any management takes place. The greenbrier thickets surrounding Site 2 were looked at briefly. This habitat also appears to be ideal and should be searched before any management takes place. No snakes were observed on this day.

Site 1 daytime surveys	**Site 2 daytime surveys**
1:00 hours	0:30 hours
Site 1 nighttime surveys	**Site 2 nighttime surveys**
none	none

2007Aug24 – While Mary Ann Furedi and Tony Davis set up vegetation monitoring plots, Charlie Eichelberger searched the perimeter of Site 1 and Site 2. On the way into the patches that will be managed, one OPAE was captured while moving through the grass close to the parking area. This was the only instance of OPAE moving along the ground in PNHP's work over the past few years on OPAE. Snake searches

at Site 1 began at 10:40 AM. One OPAE was observed but eluded capture. This snake was observed in the upper layer of greenbrier. Searches at Site 2 began at 1:00 PM. 2 adult OPAE were captured and one juvenile eluded capture during these searches. The two captured snakes were marked, and released away from the management site according to the protocols.

Site 1 daytime surveys	**Site 2 daytime surveys**
1:30 hours	3:30 hours
Site 1 nighttime surveys	**Site 2 nighttime surveys**
none	none

2007Aug28 – Tony Davis and Brad Eichelberger set up vegetation monitoring plots while Charlie Eichelberger searched for OPAE. Searches began at 9:45 AM and concluded at 2:30PM. Two new OPAE were captured, marked, and moved according to protocols.

Site 1 daytime surveys	**Site 2 daytime surveys**
none	4:45 hours
Site 1 nighttime surveys	**Site 2 nighttime surveys**
none	none

2007Sep5 – Charlie Eichelberger searched Site 1 at 3:00 PM. One fresh OPAE shed was found in the sparse Smilax at WP280. One adult northern black racer (*Coluber constrictor*) was observed. Daytime searches concluded at 7:15 PM. Nighttime searches began at 8:00 PM and continued until 9:30 PM. No OPAE were observed. Several adult American toads (*Anaxyrus americanus*) were observed as I was returning to the parking area.

Site 1 daytime surveys	**Site 2 daytime surveys**
2:00 hours	2:15 hours
Site 1 nighttime surveys	**Site 2 nighttime surveys**
0:45 hours	0:45 hours

2007Sep6 – Charlie Eichelberger began searching Site 1 at 3:30 PM. No snakes were observed during this search. At 6:00 PM, Site 2 was searched for OPAE. One new adult OPAE was captured at 7:00 PM at WP281. Nighttime searches began at 8:00 PM, with one OPAE captured at 9:15 PM in greenbrier. This OPAE was captured using a powerful flashlight.

Site 1 daytime surveys	**Site 2 daytime surveys**
2:30 hours	1:15 hours
Site 1 nighttime surveys	**Site 2 nighttime surveys**
0:45 hours	0:45 hours

2007Sep7 – Mary Ann Furedi, Greg Podniesinski, Denise Johnson, and Charlie Eichelberger arrived to search for OPAE. On the walk in to the management sites, one OPAE was captured on the powerline ROW (WP285).

Searches began at Site 1 at 7:30 AM. Two ADL OPAE were captured, marked, and moved away from the management area according to protocols. DCNR BOF workers arrived at 11:00 AM and began cutting shortly thereafter. Jay Drasher (Aqua-Terra Environmental Inc.) arrived at 11:30 AM and aided in the searches. All areas that were to be managed that day, including areas where cut brush would be placed, were searched twice thoroughly, using the protocols outlined above. One more brief search was conducted shortly before the chainsaw operators began cutting trees and brush. One more juvenile OPAE was captured (WP290) before the searches and management were completed for the day.

Site 1 daytime surveys	**Site 2 daytime surveys**
20:30 hours	none
Site 1 nighttime surveys	**Site 2 nighttime surveys**
none	none

The results of the first day of management at the Goat Hill Serpentine Wild Plant Sanctuary appear to be a success. The search protocols for OPAE described above seemed effective, as three snakes were captured and moved out of harms way during the pre-management searches. The second pre-management search of the same cleared area did not yield any OPAE captures or sightings, and the brief pass immediately before management took place, did not yield any OPAE sightings or captures, indicating that the initial searches using the developed protocols are effective. No OPAE were observed during management by searchers or chainsaw operators. It appears that no OPAE were injured or killed during this management activity. Despite the apparent success of the management, the DCNR BOF chainsaw operators and brush draggers had to leave at 2:00 PM, and searches ceased then. About ¼ of the work that was targeted at Site 1 was actually completed, and another day would be necessary to complete the management work at Site 1.

Also of note, one of the DCNR chainsaw operators was at the site the previous week for some other purpose, and happened upon an OPAE moving through *Rubus* sp. near the parking area.

2007Oct4 – Tony Davis, Denise Johnson, and Charlie Eichelberger searched Site 1 for OPAE. Searches began at 7:30 AM and were completed by 9:30 AM. Skies were overcast, and air temperature at the beginning of the survey was 21^{o}C. No snakes were observed on this day. The search time was dramatically reduced on this day because the greenbrier had senesced since the first management day on September 7th. One adult eastern box turtle (*Terrapene carolina*) male was captured near where we would be throwing brush. This turtle was marked, and moved slightly in from where brush would be piled.

Site 1 daytime surveys	Site 2 daytime surveys
6:00 hours	none
Site 1 nighttime surveys	**Site 2 nighttime surveys**
none	none

A summary of data collected for captured rough green snakes is summarized in Table 1.

Conclusions for rough green snake searches from the 2007 work at Goat Hill

The search protocols developed by PNHP and PFBC for this project appear to have been successful in minimizing any direct harm to the OPAE population at the managed area. Our searches documented that both areas that were targeted for management support rough green snakes, and the absence of recaptured snakes during all of the work would suggest that the OPAE population at Goat Hill Wild Plant Sanctuary is healthy and reproducing. Both sites targeted for management will be monitored in the following years to chart the success of reestablishment of serpentine grasslands. This monitoring will include searches for OPAE in the areas that were managed, as well as the areas immediately surrounding managed areas.

Organized daytime searches for rough green snakes resulted in 0.21 snakes/man hour, while nighttime searches yielded 0.33 snakes/man hour. These results are difficult to compare to search efforts reported in southern studies since different techniques were used (i.e. boat surveys, vs. foot surveys, apparent differences in habitat use). Eighty-five percent of rough green snake captures in Plummer's 1984 study were within 3 m of the lake shore, while none of the captures in the Goat Hill surveys were notably close to a body of water.

Future goals of the project with respect to rough green snakes include:

1. monitoring of the rough green snake population at Goat Hill Wild Plant Sanctuary
2. monitoring of permanently marked individual rough green snakes and their spatial use of habitats compared to previous spatial data collected on those individuals
3. establishment of a population estimate of rough green snakes and Goat Hill Wild Plant Sanctuary using mark-recapture software
4. further morphological and habitat use data of rough green snakes
5. further refinement and modification of rough green snake search protocols to reflect new information collected during this project

Further research regarding the rough green snake population at Goat Hill should include radio telemetry to establish the locations of hibernacula, nest cavities, as well as daily and seasonal movements. The information gathered from such a study would eliminate much of the guesswork in establishment of the search protocols

All information has been entered into the PNHP database.

Special thanks go to all PNHP and DCNR staff who assisted with rough green snake searches and habitat management in 2007. Special thanks to Sally Just of DCNR for support of the project, Chris Urban for helping draft and approve rough green snake search protocols, Tim Draude for his insights into serpentine habitat management, and Jay Drasher for volunteering with rough green snake searches.

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8/24/2007	270±5m	271±6m ○ same	OPAE	● new ○ recapture	●ADL ○JUV	○ ♀ ● ♂ ○UKN	○ gravid ● nongravid	19.0g	403mm	277mm	680mm	25 ○ not marked	● not marked
8/24/2007	272±6m	274±7m ○ same	OPAE	● new ○ recapture	●ADL ○JUV	○ ♀ ○ ♂ ●UKN	○ gravid ● nongravid	15.0g	364mm	226mm	590mm	● not marked	17 ○ not marked
8/24/2007	273±4m	± m ○ same	OPAE	● new ○ recapture	○ADL ●JUV	○ ♀ ○ ♂ ●UKN	○ gravid ● nongravid	g	mm	mm	mm	● not marked	● not marked
8/29/2007	275±9m	276±9m ○ same	OPAE	● new ○ recapture	○ADL ●JUV	○ ♀ ○ ♂ ●UKN	○ gravid ● nongravid	4.5g	234mm	124mm	358mm	● not marked	21 ○ not marked
8/29/2007	± m	277±6m ○ same	OPAE	● new ○ recapture	●ADL ○JUV	○ ♀ ● ♂ ○UKN	○ gravid ● nongravid	14.5g	370mm	253mm	623mm	● not marked	13 ○ not marked
9/6/2007	281±7m	282±7m ○ same	OPAE	● new ○ recapture	●ADL ○JUV	● ♀ ○ ♂ ○UKN	○ gravid ● nongravid	27.0g	464mm	306mm	720mm	18 ○ not marked	● not marked
9/6/2007	283±5m	284± m ○ same	OPAE	● new ○ recapture	○ADL ●JUV	○ ♀ ○ ♂ ●UKN	○ gravid ● nongravid	8.0g	292mm	178mm	470mm	20 ○ not marked	● not marked
9/7/2007	285±7m	± m ● same	OPAE	● new ○ recapture	○ADL ●JUV	○ ♀ ○ ♂ ●UKN	○ gravid ● nongravid	5.0g	239mm	131mm	370mm	● not marked	15 ○ not marked
9/7/2007	286±4m	288±8m ○ same	OPAE	● new ○ recapture	●ADL ○JUV	● ♀ ○ ♂ ○UKN	○ gravid ● nongravid	29.0g	485mm	285mm	720mm	28 ○ not marked	● not marked
9/7/2007	287±4m	289±9m ○ same	OPAE	● new ○ recapture	●ADL ○JUV	○ ♀ ● ♂ ○UKN	○gravid ●nongravid	21.0g	455mm	310mm	765mm	● not marked	24 ○ not marked
9/7/2007	290±5m	291± m ○ same	OPAE	● new ○ recapture	○ADL ●JUV	○ ♀ ○ ♂ ●UKN	○ gravid ● nongravid	4.0g	210mm	125mm	335mm	12 ○ not marked	● not marked

Table 1. A summary of data collected on all rough green snakes captured at Goat Hill Wild Plant Sanctuary during 2007 restoration-related a

Appendix B. Protocol for vegetation monitoring at Goat Hill Wild Plant Sanctuary

Pre-restoration vegetation data were collected from Sites 1 and 2 using the following protocol. The same protocol will be repeated for post-restoration monitoring.

At each site, transects were established off of a common central baseline (transects run perpendicular to the central baseline). Transects were placed equal distance apart based on a starting randomly selected distance. Transect placement was also randomly selected (placement perpendicular to either the right or left side of baseline). Transects extended from the central baseline to beyond the forest/grassland edge so that areas targeted for tree and greenbrier removal were included in the sampling. Eight transects were established at Site 1 and 14 transects at Site 2.

Once transects were in place, vegetation plots were established every three meters along each transect. Plots were 1-m x 1-m in size and all vegetation data were collected following NatureServe's accepted natural heritage sampling protocols (Strakosch-Walz 2000) (see sample of data sheet below). The vegetation was visually divided into eight strata: emergent trees (variable height), tree canopy (variable height), tree subcanopy (> 5 m in height), tall shrub (2 - 5 m), short shrub (< 2 m), herbaceous, non-vascular, and vines. All species within the plot were listed and the percent cover was estimated for each species in each stratum using modified Braun-Blanquet cover classes (Strakosch-Walz 2000). Specimens of species not identifiable in the field were collected for later identification. Data was collected for a total of 91 plots, 50 plots in Site 1 and 41 plots in Site 2.

In addition to floristic information, other environmental variables were recorded at each plot including slope, aspect, topographic position, hydrologic regime, and soil stoniness. Any unvegetated area of the plot was characterized by the exposed substrate. Notes were taken on the plot representativeness of the surrounding vegetation and any other significant environmental information, such as landscape context, herbivory, surrounding vegetation health, recent disturbance, or evidence of historic disturbance. The vegetation profile and topographic position were sketched in cross-section to represent the location and setting of the plot. The location of each plot was recorded using a Garmin GPSMAP 76CSx global positioning system (GPS) unit. The datum was recorded as North American 1983 and the coordinate system was Universal Trans-Mercator (UTM) zone 18. Each plot should be permanently marked after data collection so they can relocated for future monitoring purposes. We will mark plots in Sites 1 and 2 in 2008.

Goat Hill – Vegetation Sampling

A. Identifiers (general EOR information)

1. SITE NAME:_____ 2. SITE LOCATION:_____

3. PLOT ID:_____4. COUNTY NAME: _____

5. Lat:_ _ _ _ _ _ N Long: 0 _ _ _ _ _ _ W OR UTM Zone: 18N Datum NAD83

Easting: Northing:

6. Directions:

7. Survey date:

8. Last obs:_____ 9. First obs:_____

10. Surveyors:_____

11. Photos taken : _____(#)_____ 12. Photo Label(s): _____

13. Soil sample taken: _____ 14. Soil Label(s): _____

B. Environmental Description

15.Topographic sketch

16.Topographic description:

Elevation:_____ Slope degrees:_____

Slope aspect:_____ Parent material:

18.Soil moisture regime:

___ Extremely dry ___ Somewhat wet

___ Very dry ___ Wet

___ Dry ___ Very wet

___ Somewhat moist ___ Permanently inundated

___ Moist ___ Periodically Innundated

19.Stoniness:

__ Stone free <0.1%

__ Moderately stony 0.1-1%

__ Stony 3-15%

__ Very stony 15-50%

__ Exceedingly stony 50-90%

__ Stone piles >90%

17.Topographic position:

___ Interfluve ___ Back slope

___ High Slope ___ Step in slope

___ High level ___ Low slope

___ Midslope ___ Toe slope

___ Low level ___ Channel wall

___ Basin floor ___ Swale

___ Channel bed ___ Other (_____)

20.Soil drainage:

___ Rapidly drained ___ Somewhat poorly drained

___ Well drained ___ Poorly Drained

___ Moderately well drained ___ Very poorly drained

21.Average texture:

___ sand ___ clay loam

___ sandy loam ___ clay

___ loam ___ peat

___ silt loam ___ muck

___ other :_____

22.Soil profile description: note depth, texture, and color of each horizon. Note significant changes such as depth to mottling, depth to water table, root penetration depth (SOILCOM)

Organic horizon depth:_____

Organic horizon type:_____

23.Hydrologic regime:

___Permanently flooded ___Saturated

___Intermittently exposed ___Temporarily flooded

___ Semi-permanently flooded ___Intermittently flooded

___ Artificially flooded

___ Seasonally flooded ___ Never flooded

24.Unvegetated surface:

___% Bedrock ___% Wood (> 1 cm)

___% Large rocks ___ % Litter, duff

(cobbles, boulders > 10 cm)

___% Small rocks (gravel, 0.2-10 cm) ___% Water

___% Sand (0.1-2 mm) ___ % Other:

___% Bare soil

25.Environmental Comments: Note homogeneity of vegetation, erosion / sedimentation, inundation, etc.

26.Plot representativeness:

C. Vegetation

27.System: _____ Terrestrial _____ Palustrine _____ Estuarine 28..Plot ID: VAFO- 29.Plot dimensions: 5m x 5m

30.Leaf Type	31.Leaf Phenology	32.Physiognomic Type		33.Overall Plot data	Ht range (m)	% cover
___ Broad-leaf	___ Deciduous	___ Forest	___ Woodland	T1 Emergent tree		
___ Semi-broad-leaf	___ Semi-deciduous	___ Sparse Woodland	___ Scrub Thicket	T2 Tree canopy		
___ Semi-needle-leaf	___ Semi-evergreen	___ Shrubland	___ Sparse Woodland	T3 Tree sub-canopy		
___ Needle-leaf	___ Evergreen	___ Dwarf Shrubland	___ Dwarf Scrub Thicket	S1 Tall shrub (2-5m)		
___ Broad-leaf herbaceous	__ Perennial	___ Sparse Dwarf Shrubland	__ Herbaceous	S2 Short shrub (0.5-2m)		
__ Graminoid	___ Annual	___ Non-Vascular	___ Sparsely Vegetated	H Herbaceous		
___ Pteridophyte				N Non-vascular		
				E Epiphyte		
				V Vine / liana		

Cover Classes (CC)
R = 1 or few (+) = occasional 1 = <5% 2- = 5-12% 2+ = 13-25% 3 = 26-50% 4 = 51-75% 5 = 76+%

Species / percent cover: starting with uppermost stratum, list all species and % cover for each in the stratum. For forests and woodlands, list on a separate line below each tree species the DBH of all trees above 10 cm diameter. Separate the measurements with a comma and note whether in cm or inches. After the plot is completed, also list all species not included within the plot but within the cell where the plot is located.

Appendix C. Summary of plants observed at Sites 1 and 2 during vegetation plot sampling prior to restoration related activities

Nomenclature follows the PLANTS Database, Version 3.5 developed by the Natural Resource Conservation Service in cooperation with the Biota of North America Program (United States Department of Agriculture, National Resources Conservation Service 2004). For this report, some common names listed in the PLANTS Database were changed to reflect the common names typically used by ecologists and resource managers in this region. No asterisk: found at both sites; one asterisk: found at Site 1; two asterisks: found at Site 2.

Family	Scientific Name	Common Name
Aceraceae	*Acer rubrum*	red maple
Anacardiaceae	*Toxicodendron radicans**	Eastern poison ivy
Asclepiadaceae	*Asclepias verticillata*	whorled milkweed
Asteraceae	*Conoclinium coelestinum**	blue mistflower
	Packera anonyma	Small's ragwort
	Solidago nemoralis	gray goldenrod
	Symphyotrichum depauperatum	serpentine aster
Betulaceae	*Betula lenta**	sweet birch
Brassicaceae	*Arabis lyrata*	lyre-leaved rock-cress
Caprifoliaceae	*Lonicera morrowii**	Morrow's honeysuckle
Caryophyllaceae	*Cerastium arvense* var. *villosum* [= *C. velutinum*]	barrens chickweed
Cistaceae	*Helianthemum bicknellii**	hoary frostweed
Cladoniaceae	*Cladonia* sp.	cup lichen
	Cladonia cristatella	cup lichen
Cupressaceae	*Juniperus virginiana*	eastern red-cedar
Cyperaceae	*Carex* sp.*	sedge
Dryopteridaceae	*Polystichum* sp.*	hollyfern
Ericaceae	*Gaylussacia baccata***	black huckleberry
	Vaccinium pallidum	blue ridge blueberry
	*Vaccinium stamineum***	deerberry
Fabaceae	*Baptisia tinctoria*	horseflyweed
Fagaceae	*Quercus ilicifolia*	bear oak
	Quercus prinoides	dwarf chinkapin oak
	*Quercus stellata***	post oak
Lauraceae	*Sassafras albidum*	sassafras
Onagraceae	*Oenothera fruticosa***	narrowleaf evening primrose
Oxalidaceae	*Oxalis stricta*	common yellow oxalis
Pinaceae	*Pinus rigida*	pitch pine
Poaceae	*Aristida* sp.*	three-awn
	Aristida longespica	slim-spike three-awn
	Aristida purpurascens	arrow-feather three-awn

Family	Scientific Name	Common Name
Poaceae (cont.)	*Dichanthelium depauperatum*	starved panic-grass
	*Dichanthelium dichotomum***	forked panic-grass
	Dichanthelium sphaerocarpon	round-fruited panic-grass
	Dichanthelium villosissimum	long-haired panic-grass
	Eragrostis spectabilis	purple love-grass
	*Muhlenbergia schreberi**	nimbleweed
	Panicum sp.	panic grass
	Panicum capillare	witchgrass
	*Panicum philadelphicum**	Philadelphia panic grass
	Schizachyrium scoparium	little bluestem
	Sorghastrum nutans	Indian-grass
	Sporobolus heterolepis	prairie dropseed
Polemoniaceae	*Phlox subulata*	moss phlox
Polgalaceae	*Polygala verticillata*	whorled milkwort
Polygonaceae	*Polygonum tenue*	slender knotweed
Portulacaceae	*Phemeranthus teretifolius**	round-leaved fame-flower
Rosaceae	*Potentilla simplex*	common cinquefoil
	Prunus serotina	black cherry
	*Rosa multiflora**	multiflora rose
	*Rubus pubescens***	dwarf red blackberry
Smilacaceae	*Smilax glauca***	cat greenbrier
	Smilax rotundifolia	roundleaf greenbrier
Violaceae	*Viola sagittata**	arrowleaf violet
Vitaceae	*Vitis* sp.*	grape

Appendix D. Plant species of special concern in Pennsylvania found at Sites 1 and 2 at Goat Hill Wild Plant Sanctuary

The following is a list of plant species of special concern in Pennsylvania found at Sites 1 and 2 at Goat Hill. This list was compiled from a survey of these sites conducted in August 2007. No asterisk: found at both sites; one asterisk: found at Site 1; two asterisks: found at Site 2.

Scientific Name	Common Name	PA status
Packera anonyma	Small's ragwort	PR
*Phemeranthus teretifolius**	round-leaved fameflower	PT
Sporobolus heterolepis	prairie dropseed	PE
Symphyotrichum depauperatum	serpentine aster	PT

*Pennsylvania status codes:

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