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TITLE: **NATURAL LANDS MANAGEMENT AND STEWARDSHIP PLAN FOR HARRIET WETHERILL PARK IN PLYMOUTH TOWNSHIP, PENNSYLVANIA**

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ABSTRACT:

The Plymouth Township Parks and Recreation Department recently created Harriet Wetherill Park, a 66 ½ acre park encompassing agricultural lands, wooded areas, streams, fields, and a farmstead. Caring for the natural areas of the park presents a new challenge to the township; the other parks maintained by the parks and recreation department are designed for active recreation. The purpose of Harriet Wetherill Park is passive recreation and nature education.

To help them achieve their goals for the park, Plymouth Township contracted with Land Concepts Group, LLC in 2011 to develop a conservation and management plan for Harriet Wetherill Park. The Morris Arboretum Urban Forestry Consultants (MA-UFC) were brought on by Land Concepts to write the natural lands management and stewardship portion of the plan. This plan builds on work already undertaken by the Natural Lands Trust (NLT) at the park; it also follows the format for a stewardship plan recommended in NLT's Stewardship Handbook (Steckel and others 2008).

The challenges for the natural areas of the park are the limited diversity of vegetation due to both deer browse and the prevalence of invasive plant species on site; the fragmentation of the wooded areas; and the lack of a riparian buffer zone in parts of the park. Erosion is also a concern in several areas. This stewardship plan outlines the steps to take to meet these challenges, prioritizes management activities, and provides a management calendar for the park. A stewardship manual will be provided to Plymouth Township Parks and Recreation in May 2013.

Natural Lands Management and Stewardship Plan for Harriet Wetherill Park in Plymouth Township, PA

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GENERAL AND BACKGROUND INFORMATION

Harriet Wetherill Park, located in Plymouth Township, Montgomery County, PA is a 66 ½ acre park comprised of agricultural lands, wooded areas, streams, fields, and the former farmstead of Mr. and Mrs. Elkins Wetherill. Approximately 40 acres of the park was acquired by Plymouth Township in 1996 and the remaining acreage in 2006. The park is in the Reading quadrangle (USGS) with coordinates of 40.117222º N and 75.268889 º W at its approximate center.

Harriet Wetherill Park (HWP) is located about one mile from Plymouth Meeting Mall, with the main entrance from Narcissa Road and a second entrance, leading to the main house, from Butler Pike. A new main entrance is planned off of Butler Pike. Both current entrances are accessible by vehicle; there are no designated trails leading into the park and the adjacent roads are not easily used by either pedestrians or cyclists. The nearest public transportation is the L bus that stops at Plymouth Meeting Mall.

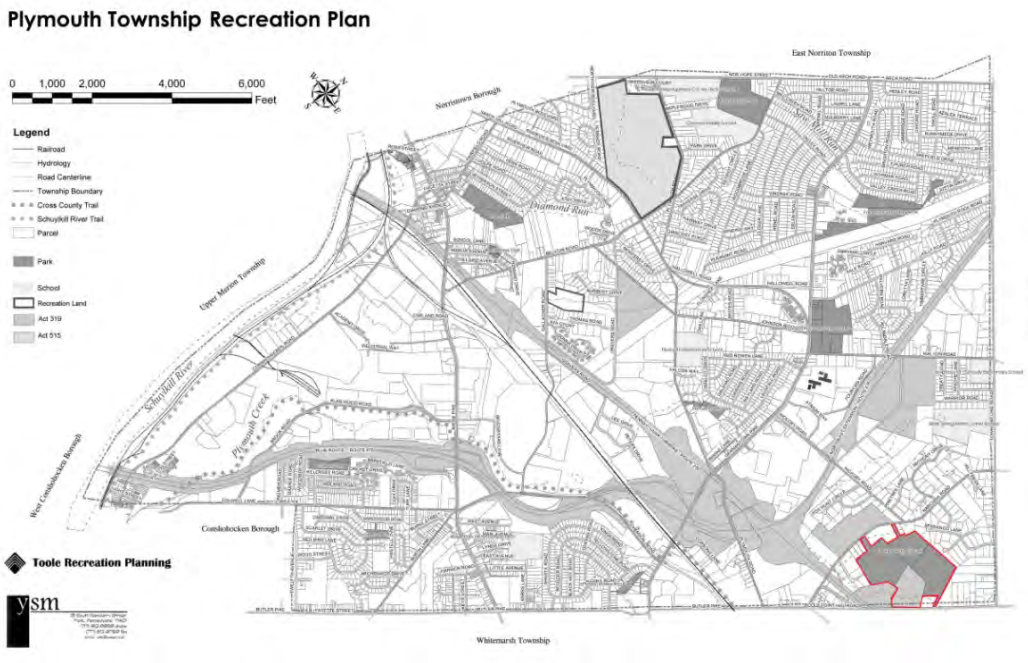
Regional context

Harriet Wetherill Park is the only parkland in Plymouth Township with considerable wooded and natural areas. Parts of the land have been in agriculture for many decades and, with the decline of farming elsewhere in the community, now showcase the region's agriculture heritage. The park is surrounded by suburban-sized individual home lots on most of its edges. South of the park, the adjacent parcel of land is protected under Act 319 as Clean and Green Land, i.e. land that the owner agrees to keep as woodland, farm, or pasture (YSM 2007).

Map 1 Aerial photograph of Harriet Wetherill Park showing park boundary.

HWP is connected to the larger community through its waterways: Plymouth Creek and its tributaries flow through the park and eventually into the Schuylkill River and the park provides a large, non-paved area for stormwater infiltration. Agricultural crops grown in the park by Maple Acres Farm are sold to residents of Plymouth Township and the surrounding area, meaning that

some community members are connected to HWP in a very physical way: they eat food grown there.



Harriet Wetherill Park is the largest park in Plymouth Township and the only park with considerable natural wooded areas.

Map 2 Harriet Wetherill Park shown in relation to other park land in Plymouth Township.

Goals for Harriet Wetherill Park

In accordance with Mr. Wetherill's wishes, Plymouth Township intends that the land be used to protect open space, preserve the natural resources currently onsite, and maintain the cultural context of the farm property in the midst of a suburban area. Goals for the park include:

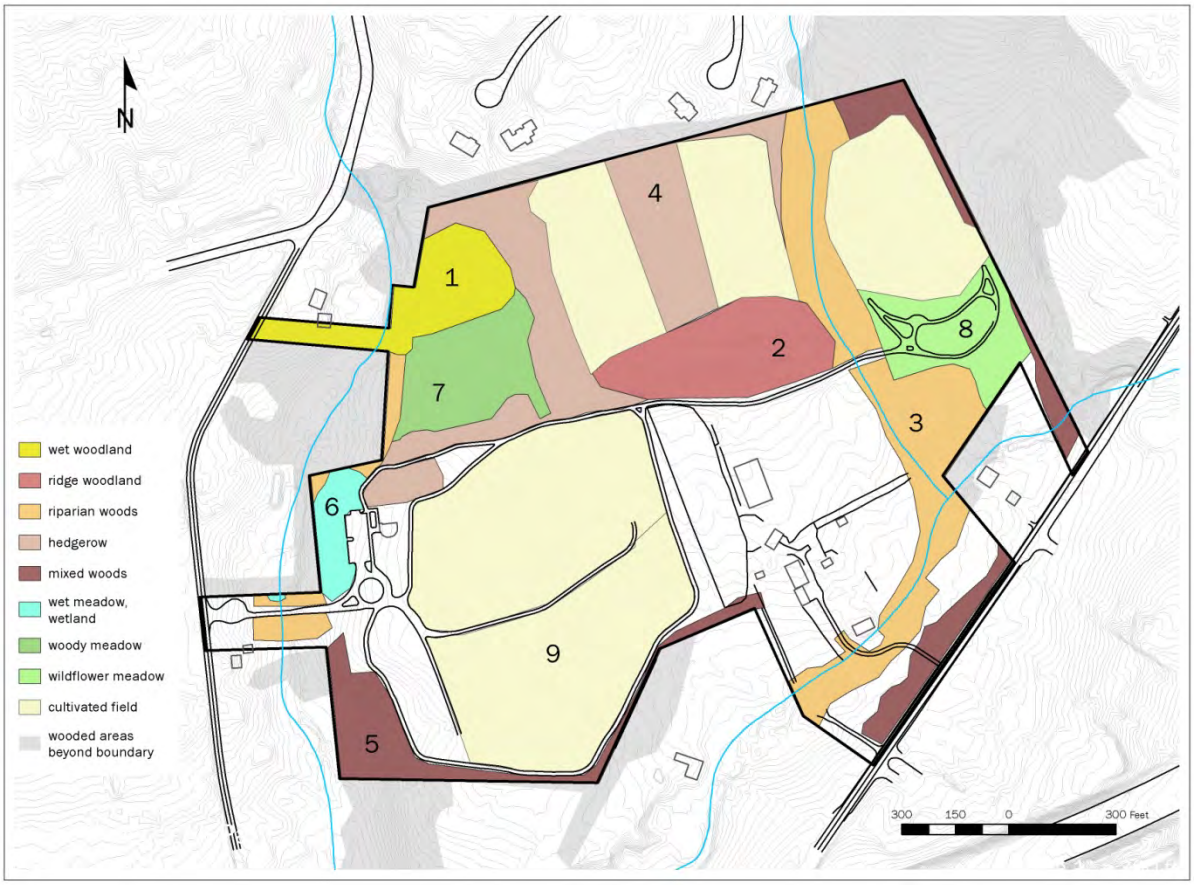
- Passive recreation opportunities
- Environmental education
- Enjoyment of the outdoors
- Reconnection with the agrarian and equestrian heritage of the region
- That it be revenue-neutral.

NATURAL RESOURCES INVENTORY AND ANALYSIS

Before making stewardship recommendations for the improvement and continued care of the park, an inventory of the natural resources at HWP was needed. The following sections detail these natural resources.

MA-UFC identified 9 cover types at HWP, 5 wooded and 4 more open cover types. These types reflect the topography and soils that underlie them as well as the kind and frequency of disturbance they have been subject to. Most of the disturbance has been due to site management activities undertaken intentionally. Different portions of the park have been variously maintained through agricultural practices (like tilling and sowing), mowing, garden planting, and tree planting. Some areas were left to grow with minimal disturbance.

At the end of each section we have also provided the term used by the Natural Lands Trust in their 2011 report for HWP, for continuity.



Map 3 Vegetation cover types at Harriet Wetherill Park.

1. *Wet woodland*

The wet woodland canopy layer contains red maple (*Acer rubrum*), silver maple (*Acer saccharinum*), and white ash (*Fraxinus americana*). Elms (*Ulmus rubra, U. americana*) and sycamore (*Platanus occidentalis*) were also observed, as well as pin oak (*Quercus palustris*). Walnuts (*Juglans nigra*) increase upslope from the creek tributary.

The canopy is thin and not much seedling recruitment was in evidence. The ash trees are in decline; the dieback is not due to emerald ash borer (*Agrilus planipennis*) damage since the exit holes in the trunks were round, not D-shaped; D-shaped exit holes are diagnostic for emerald ash borer (EAB). Additionally, EAB has not yet been documented in this part of Pennsylvania. Similar decline in ashes in other areas of Pennsylvania and New Jersey has been observed and ascribed to ash yellows; Jason Lubar (MA-UFC) thinks that this is not the case here. It is unclear what is causing ash decline at Harriet Wetherill Park.

The wet woodland understory is largely privet (*Ligustrum obtusifolium*), crabapple (*Malus sp.*), and multiflora rose (*Rosa multiflora*), with buckthorn (*Rhamnus cathartica*) present along the edges of the woods. Much of the multiflora rose has rose rosette disease. Arrowwood viburnum (*Viburnum dentatum*) and spicebush (*Lindera benzoin*), both native understory plants, were observed upslope from the wettest areas.

The herbaceous layer supports sensitive fern (*Onoclea sensibilis*) and agrimony (*Agrimonia* sp.), plants that need some sun and wet conditions. Stiltgrass (*Microstigium vimineum*) covers the ground in the sunniest areas. Sedges (*Carex* sp.), rushes (*Juncus* sp.), and deer tongue grass (*Dichanthelium clandestinum*) are also present.

NLT designation: red maple palustrine forest

2. *Ridge woodland*

The wooded ridge in the middle of the park has some of the oldest and largest trees at Harriet Wetherill – some trees appear to be over 120 years old (informal tree ring count by Jason Lubar, MA-UFC). Red oak (*Quercus rubra*), white oak (*Quercus alba*), and shagbark hickory (*Carya ovata*) compose the canopy layer; ash, hackberry *(Celtis occidentalis*), and Norway maple (*Acer platanoides*) are also present. There is visible regeneration of ash and hickory.

The ridge woodland supports late-successional tree species and serves as a seed source of these species for the adjacent hedgerows. In the nearest hedgerow, more oaks were observed in the portion closest to the ridge woodland.

There is a gap in the canopy at the top of the ridge and the sunny area is covered in stiltgrass and garlic mustard (*Alliaria petiolata*). This area has exposed rock in some areas and shallow soil in others, which might not support shrubs and trees. Bush honeysuckles (*Lonicera* sp.) are present lower on the ridge, especially on the west and south sides. Garlic mustard is rampant on the southwestern slope of the ridge. In March 2013, the first-year rosettes were forming. Garlic mustard is a biennial plant, forming a rosette in year 1 and becoming a tall plant in year 2 before setting seed and dying.

Spring ephemeral plants found on the ridge include spring-beauty (*Claytonia virginica*), yellow trout-lily (*Erythronium americanum*), and bloodroot (*Sanguinaria canadensis*). These plants emerge in the early spring before the tree canopy leafs out and they flower and set seed before the canopy closes in May. For the rest of the year, spring ephemeral plants die back to their underground parts and re-emerge the following spring.

Lesser celandine (*Ranunculus ficaria*), found in some parts of the ridge woodland, is also a spring ephemeral but is not native to the area and is considered invasive by the USDA. It forms a dense carpet and can impede native spring ephemerals. Other spring-blooming plants of interest in the ridge woodland are hairy Solomon's seal (*Polygonatum pubescens*), false Solomon's seal (*Maianthemum racemosum*), and Jack-in-the-pulpit (*Arisaema triphyllum ssp. triphyllum*).

NLT designation: red oak – mixed hardwood forest

3. *Riparian woodland*

The woods along tributary no. 5 of Plymouth Creek have been the site of recent tree plantings: maples, birch, and cryptomeria (*Cryptomeria japonica*) were observed in late summer 2012. Several of these had died by the spring of 2013.

Ashes and maples compose an increasing percentage of the canopy moving further along the creek, away from the ridge woodland. Some canopy dieback is in evidence along the stream, especially among the ashes.

Privet and grape *(Vitis* sp.) are found in the shrub layer, with more bush honeysuckle approaching the park boundary. Bottlebrush grass (*Elymus hystrix*) grows near the end of the ridge heading towards the creek. Several skunk cabbages (*Symplocarpus foetidus*) were up in March, surrounded by lesser celandine.

NLT designation: red maple palustrine forest

4. *Hedgerows*

   The canopy in the hedgerows is mostly ash and walnut; as elsewhere at HWP, the ash trees are showing signs of decline. Closer to the ridge area, oak species, cherries (*Prunus* sp.), and hawthorns (*Crataegus* sp.) are in evidence.

   The understory is a riot of shrubs and vines: grape grows over shrub honeysuckle and multiflora rose, with buckthorn along the borders. More berries and lusher vegetation were observed on the sunny sides of the hedgerows (the southwest sides) than on the shadier sides.

   In wetter hedgerow areas, New York ironweed (*Vernonia noveboracensis*) was in bloom during the August 2012 site visit.

   NLT designation: mixed hardwood forest.

5. *Mixed woods*

   Other areas of Harriet Wetherill Park with some canopy cover were designated as mixed woods by MA-UFC. In some places there is only light cover – a strip of wooded area a few trees wide that serves as a buffer between the park and neighboring properties or Butler Pike, e.g. Other mixed woods areas are the edges of small woodlands that extend off-site.

   NLT designation: mixed hardwood forest.

6. *Wet meadow and wetland*

   The constructed rain garden that detains runoff from the parking lot is now primarily cattails (*Typha latifolia*). According to a DCNR report, this area was planted with native meadow grasses and wildflowers when it was installed but few of these appear to have survived in the basin itself (PA DCNR 2011). The wet meadow area adjacent to it does have a mix of wildflower and meadow species adapted to wet areas. The rain garden vegetation is not terribly diverse, but cattails are native, functional, and require little to no maintenance.

   Harriet Wetherill Park also has 0.231 acres of delineated wetland that sits just beyond the Narcissa Road entrance. Like the area below the parking lot, the wetland is mostly cattails. Any disturbance in the delineated wetland would be subject to regulation by the U.S. Army Corps of Engineers and the Pennsylvania Department of Environmental Protection.

7. *Woody meadow*

   Woody clumps and hedgerows support fast-growing trees: black walnut, cherry, and silver maple. The understory of the clumps is composed of invasive shrubs also found elsewhere on site: buckthorn and multiflora rose, with Japanese honeysuckle growing over the tops. Some of the clumps of trees in the woody meadow have formed around evergreens: Eastern white pine (*Pinus strobus*) and Eastern redcedar (*Juniperus virginiana*).

   The open areas of this meadow support generalist herbaceous species, including a number of grasses documented by Mr. Wetherill. Chinese silver grass (*Miscanthus sinensis*), which is considered invasive, can be seen spreading along the edges of the hedgerows. Poison ivy (*Toxicodendron radicans*) grows in patches in the open areas.

   The hedgerows are encroaching on the woody meadow in the northwest of the park; the vegetation today extends much further than shown on the 1942 map, and subsequent maps show a few feet of encroachment approximately every 10 years.

   NLT designation: terrestrial meadow

8. *Wildflower meadow and butterfly garden*

   The butterfly garden was an early action item from the HWP Master Plan completed in 2007. The garden has been the focus of several volunteer days, where neighbors and members of local businesses and organizations undertake weeding, path maintenance, and planting. The butterfly garden paths were re-paved in February 2013 by the parks and recreation department.

   Below the walkways in the garden is a wildflower meadow, some of which was also planted.

   On the March 2013 site visit, it appeared that there were three butterfly bushes (*Buddleja* sp.) that had been planted near one of the stone retaining walls. The most popular species of butterfly bush, *Buddleja davidii*, is an invasive species and should not be planted. MA-UFC was not able to determine which species were used in the butterfly garden, but only seed-sterile cultivars of butterfly bush should be planted.

   NLT designation: terrestrial meadow.

9. *Cultivated fields*

   The largest cultivated area at HWP, in the southwest corner, is currently farmed by Maple Acres Farm. The two areas to the north are to be leased for farming also, although maybe not to the same operation. These areas will be planted and cared for by tenants.

   The area in the northeast corner, north of the butterfly garden, is currently similar to other open, uncultivated areas on site. It is mown regularly, preventing the establishment of woody species. Its future use, and hence cover type, is yet to be determined, but it has been discussed as an area for pasture or a warm season grass meadow and is suitable for both uses.

   As stated in the hydrology section, the fields all drain to either Plymouth Creek or its tributaries. Drainage patterns need to be taken into account if these fields are ploughed or re-graded for any purpose or if amendments are used on fields.

   NLT designation: agricultural fields.

Species and communities of special concern

The oldest trees on site are found in the ridge woodland, as are many of the spring ephemeral plants. As the least-disturbed area, the ridge is a priority for protection. The wet woodland also supports a diversity of plant species and is only moderately invaded. Finally, protecting and enhancing the riparian corridors is a high priority because they form part of a network extending beyond the park's boundaries and provide many ecosystem services.

Species of concern include the invasive woody shrubs, vines, and herbaceous plants colonizing the site. Management activities detailed below will address these species. There are a number of species of deciduous shrubs and woody vines that are considered invasive; invasive species make up nearly half of the diversity of deciduous shrub and woody vine species on site.

STEWARDSHIP ISSUES

Deer browse

Deer are the greatest threat to biodiversity and ecosystem functions on site. White-tailed deer populations on the East Coast have reached levels not seen in the previous two hundred years and are highest in areas with mixed forest and agricultural fields, where there may be 60 deer/km^2 (Horsley and others 2003).

The overabundance of deer affects the development and species composition of vegetation – plants that deer prefer disappear quickly and unpalatable plants come to dominate. For example, deer prefer not to eat ferns, so in areas with heavy deer activity, ferns may be the primary plant in the herbaceous layer.
When hardwood seedlings do manage to grow through the mat of ferns, they are then eaten by deer (Horsley and others 2003). Deer inhibit regeneration of many tree species, leading to a forest with older native trees in the canopy but few younger native trees growing up to replace the older ones.

At HWP, the pressure of deer browse is evident across the site. The active agricultural fields are fenced to protect the crops inside. Outside the fences, unpalatable and/or non-native shrubs are the primary vegetation in the hedgerows and ferns and sedges are a large part of the herbaceous layer in the wet woodland.

A deer exclosure – an area of woodland fenced off to exclude deer – could increase the diversity of native plants at HWP and be a useful educational demonstration. Seeds of species that are heavily browsed by deer – viburnum or Eastern hemlock, e.g. – may be present in the seed bank and may regenerate once the deer are excluded. An exclosure would give park users a chance to see a greater variety of native vegetation and learn about the impact of white-tailed deer on the East Coast. Exclosure fencing would require regular maintenance and occasional repair.

If fencing a larger area is not an option for aesthetic or maintenance reasons, a deer repellant could be applied to new plantings, especially young trees and shrubs. The Philadelphia Parks and Recreation Department is currently using a spray-on deer repellant (PlantSkydd®; similar products could also be used) with an odor that triggers a fear response in deer to protect new plantings in restoration areas (Luke Rhodes, Philadelphia Parks and Recreation, personal communication). Some deer repellants are listed as organic by the Organic Materials Review Institute (OMRI) and could be applied by anyone, park staff or volunteer, without a pesticide applicator's license.

Fencing on individual trees can also be used. A thick plastic mesh is preferable to other types of tree fencing because it allows air to flow easily around the trunk, preventing dampness

and rot. This can also help prevent bucks from rubbing young trees to death, although in some instances they are able to hike up the fencing and get to the tree trunk regardless of the fence type used.

Planting larger trees with most of their foliage above the browse line (the height deer can reach) may be another option, although large trees are much more expensive. Moving and planting large trees also disturbs more soil, and the equipment used can cause soil compaction.

In short, most if not all new plantings will need to be protected from deer. Even shrubs that are not usually eaten by deer will be browsed if the deer population is high in an area, and any woody plant is susceptible to rubbing by bucks.

Invasive plant species

Invasive plant species at Harriet Wetherill Park also threaten plant diversity. As defined by Federal Executive Order 13112, invasive species are species that are foreign to the ecosystem under consideration and whose introduction causes or is likely to cause harm, either to the environment, to economic interests, or to human health (qtd in PA DCNR 2011 p. 3). Invasive species may be very successful at reproducing, photosynthesize for a longer period of time than other plants, or benefit from a lack of competitors and predators and therefore come to dominate the area in which they establish.

Invasive plant species and species that are overly aggressive to the detriment of other vegetation found at Harriet Wetherill include:

Herbaceous layer: Garlic mustard; stiltgrass; bull thistle (*Cirsium vulgare*); Chinese silver grass

Shrub layer: bush honeysuckles (*Lonicera maackii, L. morrowii,* and *L. standishii*); multiflora rose; buckthorn; wineberry (*Rubus phoenicolasius*); autumn-olive *(Elaeagnus umbellate*); privet

Woody vines: Japanese honeysuckle (*Lonicera japonica*); wisteria; oriental bittersweet (*Celastrus orbiculatus*); English ivy (*Hedera helix*)

Canopy: Norway maple (*Acer platanoides*); tree-of-heaven (*Ailanthus altissima*)

Of these, the most important to address are the woody vines, as these can smother desirable trees and shrubs, and the invasive shrubs.

Woody vines can generally be managed by pulling up small ones and cutting large ones, then painting the cut surface with glyphosate while the cut is still fresh. Fragments of roots left in the soil will re-sprout, so it is necessary to do this through multiple seasons. Some, like Japanese

honeysuckle, keep their leaves later into the fall and can be sprayed with glyphosate when other plants are dormant (Kaufman 2007 p. 193). Any vines growing up into trees should be cut to prevent them from girdling the tree, limiting its available light and making it top-heavy and susceptible to wind throw.

Most invasive shrubs are best managed by cutting and then painting the cut stump with herbicide. They are generally too large to be pulled out and digging them out disturbs so much soil that it is often more detrimental than helpful. It may be necessary to cut and paint several times; at least one of these times should be in late summer when the plant is low on resources. Juvenile shrubs can be pulled out mechanically using a WeedWrench™ or similar puller.

The shrub honeysuckles leaf out earlier in the spring than other plants and keep their leaves later in the season, making early spring and fall good times to distinguish them from native vegetation. Their dense growth inhibits tree seedlings and herbaceous plants (Kaufman 2007 p.169). The shrubs do provide nesting habitat and a food source for birds in the winter, so once control has been established over the invasive shrub honeysuckles, native shrubs with winter fruits like winterberry holly (*Ilex verticillata*) and possumhaw viburnum (*Viburnum nudum*) should be planted and protected from deer.

The multiflora rose at HWP has rose rosette disease, which often kills host plants within a few years. Since multiflora rose is an invasive shrub, controlling it biologically through rose rosette disease is desirable. However, rose rosette disease also infects ornamental roses, which may be growing in some of the homes near the park. The Virginia Cooperative Extension does recommend removing multiflora rose within 100 m of areas where there are cultivated roses (Hong and others 2012). Plymouth Parks and Recreation could decide to let rose rosette disease take care of the multiflora rose in the wet woodland if there are no nearby cultivated rose populations.

In addition to limiting the spread of existing invasive plants, park stewards at HWP should take care not to introduce more invasive species. The proposed construction of the nature center has a chance of introducing more seeds of invasive species through soil brought in. The Pennsylvania Department of Conservation and Natural Resources (PA DCNR) recommends requiring contractors to share responsibility for preventing the introduction of invasive species on machinery or through fill. One way of doing this is by making them responsible for cleaning up any outbreak at a job site for a set amount of time after completion (PA DCNR 2011 p. 18).

Edge effects

An edge is where two habitat types meet each other – where grasses abut woodland, for example. Harriet Wetherill Park consists of primarily edges. In many areas of the park, an agricultural field, a cover type that is structurally simple and has relatively low plant species diversity, adjoins a wooded area. As they are currently managed, some of these are hard

transitions – straight mown lines. Soft, wavy edges and gradual transitions (mown grass to tall grass to shrubs to trees) are preferable because they check the effectiveness of predators like hawks and give shelter to small mammals. The township parks & recreation department has begun creating these types of planted transition zones between the farmstead and main agricultural field and as a buffer between the park and adjacent properties, where trees and shrubs are planted into unmown areas rather than turf grass.

Edges are prime browsing grounds because of the abundance of leafy vegetation. The availability of sunlight leads to greater flowering and fruiting too, so edges offer many nectar and fruit sources for wildlife. This makes edges excellent hunting areas for predators as well – they go where the herbivorous animals are.

In addition to increased sunlight penetration, especially on southern edges, wind and dust deposition are greater along woodland edges. How far edge effects penetrate into a wooded area varies, but in a survey of edge effect studies, effects were frequently measured up to 40m within the woodland (Murcia 1995). Taking 40m (around 130 feet) as a rough estimate of how far edge effects extend, HWP is almost all edge; see map 5 below. The wet woodland area is large enough to have an interior reasonably protected from edge effects; other potential interior wooded areas are located offsite but could be strengthened by expanding the adjoining wooded areas within HWP.

Lack of riparian buffers

DCNR recommends a 100 foot buffer along streams and creeks in Pennsylvania. Forested buffers remove more pesticides and nitrogen than grass buffers, help prevent stream erosion and increased sediment loads in the stream, and keep the water temperature cooler in summer (TreeVitalize 2013). While a wooded buffer is not possible everywhere at HWP, it is a good goal to keep in mind.

TreeVitalize enabled the planting of some trees in the riparian zone along tributary no. 5 of Plymouth Creek; more planting needs to take place here. The ash trees in this area are in decline and will need to be supplanted with other species; these should be planted soon so that they grow large enough to take the place of the ashes once they die. Appropriate species for planting here include pin oak (*Quercus palustris*), native maples, and river birch (*Betula nigra*).

The portion of Plymouth Creek that runs between the farmstead and Butler Pike is not well buffered – understandably so, since views into the park and from the homestead are important, as is access. But there is high potential for erosion if pasture area for the TBD-tenant of the farmstead is extended to the creek. Some planned views could be preserved and the tree cover increased in other areas. In addition to the ecological benefits of a wooded stream buffer, if the trail system runs along this portion of the creek, going in and out of sunlight and through shady areas would be a pleasant experience.

An increased wooded buffer along the creek would keep the sight and sound of Butler Pike from intruding into the park in the future. In some years' time, this portion of the trail between the creek and the pike could be wooded and shady, cooling for both the life in the creek and the park visitors. One or two gaps in the buffer could be kept to provide a glimpse of the farm house from the pike.

Erosion

Rogue trails and deer paths that become informal trails should be closed. The most effective way to close a trail is to make it very difficult to walk on – hummocky and grown-over in appearance (McCarthy 2013). This can be done by placing logs and brush on the trail or with berms or rock piles, depending on the materials available nearby.

New trails should follow contour lines wherever possible to minimize erosion. Trails that do cross contour lines can be constructed with cribbing – logs placed like stair risers along the contours of a slope – to divert water from the trail and prevent it from slowing downslope quickly (Jones Sauer 1998 p. 255).

LAND MANAGEMENT

Stewardship units

Stewardship units were mapped according to cover type, which reflects the topography, soils, moisture levels, and past management practices on site; see map 5 above. All wooded areas and the woody meadow, wet meadow, wetland, and butterfly garden (areas 1 – 8) are to be managed by Plymouth Township Parks and Recreation. The pasture and agricultural fields will be managed by the lessees; their management is outside the scope of this report.

Stewardship goals

The primary goal for stewards of the natural areas of HWP is to increase the quality of habitat through a greater diversity of native vegetation: more species and better-developed layers. Secondary goals include allowing for environmental education and recreational access and enhancing the riparian buffer around Plymouth Creek and its tributaries.

Stewardship strategies and tasks

These include work that protects natural resources already existing at HWP, routine and periodic tasks, work that increases public use and access at the park, and monitoring tasks.

Protecting and enhancing existing natural resources

1. *Wet woodland*

   The most important tasks in the wet woodland are closing off rogue trails to prevent erosion and fragmentation and stabilizing the existing trails on the woodland edge. As of April 2013, there are no trails proposed through the main part of the wet woodland. Discouraging access to the woodland interior will protect vegetation from trampling.

   In the near future (<5 years), new trees should be planted, since there is little sign of natural regeneration of canopy trees. Ash trees form a large percentage of the canopy in the wet woodland. Ash trees at the park are showing signs of decline and many have died already; MA-UFC inventoried 57 dead ash trees in the park in 2012; ash species were 80% of the total dead trees inventoried. As the ashes die, larger gaps in the tree canopy will open up. To preserve the dappled light present in the wet woodland, additional trees need to be planted to replace the dying ash. These new trees should be protected from deer browse and rub, either by fencing or by a deer repellant.

   If HWP wants to introduce additional native grasses and sedges, the wet woodland area would be a good place to plant shade-tolerant, wet-loving species. Appropriate species for planting can be found in the *Stewardship Handbook for Natural Lands in Southeastern Pennsylvania* (Steckel DB and others 2008 pg. 108).

2. *Ridge woodland*

   The garlic mustard and stiltgrass on the top of the ridge woodland and throughout the southwestern slope should be addressed immediately, as they form a manageable patch of invasive plants in woods that are otherwise in fair condition. Garlic mustard is a biennial plant that forms basal rosettes in the first year and then stalks, flowers, and seeds in its second year. The rosettes emerge in the early spring, in March, and are green before many native plants. They are easy to pull when they are young; this would be a good volunteer activity. If it is removed before setting seed, fewer plants come up the following year and pulling can continue until there are very few plants present (Tracy Beerley, Morris Arboretum, personal communication). Stiltgrass can also be hand-pulled since its roots are shallow. Pulling should be done before it flowers and sets seed; flowering usually begins in August.

   Japanese honeysuckle vines can be hand-pulled or cut at the base and the cut area painted with glyphosate. Since HWP is park land, glyphosate can only be applied by someone with a pesticide applicator's license – either park staff or a contractor. It's best to do this work in late summer or early fall (July to October) when the plant is heat-stressed and its resources have been depleted. When weighing pulling vs. cutting and painting, consider the amount of soil that would be disturbed by pulling. Freshly upturned soil will probably be colonized by an invasive plant species if it is not planted immediately by park staff.

   Disturbing the soil in areas of the ridge woodland could also uproot spring ephemeral plants, especially if the disturbance happens when these plants are dormant and cannot be seen aboveground. Spring ephemeral plants should be flagged so that they can be protected during invasive removal or trail-building activities. These plants are only visible in the spring, emerging before the canopy leafs out and disappearing once the canopy closes in mid-May.

   If the township decides to install deer fencing beyond what agriculture at the park requires, the ridge woodland would be the best candidate for fencing or other form of protection from deer browse. It is an easy area to isolate and contains some of the oldest trees in the park.

3. *Riparian woodland*

   As in the wet woodland, one of the most important tasks in the riparian corridor is to limit erosion. There are trails/deer paths along the creek presently – these should be formalized as trails and maintained or else closed.

Some tree planting has already been done and more could be done to help close canopy gaps and shade the creek. The riparian buffer should be wide (100' is encouraged) and dense where possible.

4. *Hedgerows*

   The hedgerows are currently an immense seed bank of invasive exotic seeds and have less native vegetation in them and fewer native plant species than other parts of HWP. This makes them a good place to direct efforts initially, when testing out control methods. In general, invasive shrubs should be cut and their stems painted with glyphosate, since they are difficult to uproot once established. Woody vines growing up into trees should be cut.

   Since there is extensive invasive plant removal work that could be done, it is best to start small and focus on a single area. This will let park staff and volunteers see results more quickly and reduce volunteer fatigue. MA-UFC recommends starting work in 1) the ridge woodland and 2) the area of hedgerow nearest to the ridge woodland. Starting here will lessen the threat to the ridge woodland itself from invasive species and provide an area in one of the hedgerows for native species present along the ridge to eventually spread into.

   If any invasive removal is done by contractors, Plymouth Township should specify that equipment be cleaned prior to coming onto the site and all plant material should be properly disposed of offsite. Equipment with soil on it from other projects can introduce new invasive species into the park.

   The soil in the hedgerow areas may not be ready for new tree planting for several years; MA-UFC recommends that park stewards concentrate on invasive plant removal and improving soil quality for the first 2 – 3 years. This will also give staff a chance to observe the vegetation already in the park before introducing more. Thinking in terms of forest succession, the hedgerows are in a mid-successional state and therefore early or mid-successional species native to the northeastern U.S. are appropriate for planting (Sarah Low, US Forest Service – Philadelphia Field Station, personal communication). Early successional species typically germinate near the surface and require high amounts of light and greater temperature fluctuations than later-successional, close-canopy species (Bazzaz 1979). These are the conditions that will be present in the hedgerows, especially as shrub removal occurs.

5. *Mixed woods*

   Areas of mixed woods that act as buffers for neighbors and limit visibility into and out of the park should be strengthened with additional plantings. Adding plants will also help clarify the park boundaries.

A few instances of dumping yard waste were observed; these areas should be cleaned up and signs should be posted discouraging dumping.

6. *Wet meadow and wetland*
   While not diverse, the cattails do not present a problem in the wet areas. Cattails respond to rich soils – which might be expected due to runoff from nearby cultivated fields – by putting on biomass and out-competing other vegetation. They are native and are confined to the very wet areas; they have little impact on other plants on drier portions of the site. MA-UFC recommends focusing on other areas of the park and letting the wet, low places remain cattails.

7. *Woody meadow*
   The woody meadow has a number of attractive herbaceous species and woody clumps of trees. Vines growing up into the canopy in the clumps should be cut and painted. These vines are a manageable size and since the clumps are isolated, this makes a good and manageable initial project.

   Poison ivy, although a native plant with good wildlife benefit and fall color, it is undesirable along trails and should be removed.

8. *Wildflower meadow and butterfly garden* and *9. Cultivated fields*
   These areas are intensively managed landscapes and fall outside of the 'natural areas' scope of MA-UFC's work.

Routine tasks

Wooded areas should be monitored periodically for hazardous trees, especially along trails and roads. This should be done by a certified arborist trained in tree risk assessment. Yearly monitoring along heavily-used areas would be appropriate; in areas of the park with less use, every 3 years would be acceptable. The wooded areas along paths should also be inspected after heavy storms.

Trails should be cleared of debris and encroaching vegetation. This is most important in late summer when vegetation is at its height but can be done any time.

HWP is designed to be a carry-in, carry-out park. At the edges of the park, there are some organic dump sites where yard waste and grass clippings have been deposited. This material should be removed and the areas should be monitored for future dumping. Signs can be posted in the area to discourage dumping – either warning signs or simply signs stating that the area is part of Harriet Wetherill Park. If dumping is a continued problem, Plymouth Township may need to reach out to the park's neighbors, either through mailers (maybe informational mailers letting them know that they have an excellent natural resource next door and outlining some things they

can do to be good stewards of it – including not dumping yard waste) or personal communication. The boundaries of HWP also need to be clearly delineated. These activities can be done any time but may be good winter activities when other park work slows.

Mulching in the most-maintained areas of HWP (currently the butterfly garden) will need to be done twice annually, and weeding in these areas needs to be done several times per year. It is best to mulch in the spring after the soil warms up (mulching cold soil can keep it cold longer and delay plant growth) and again the late fall after the soil freezes. Plymouth Township Parks and Recreation currently schedules monthly butterfly garden volunteer days during the spring and summer months; this is a great idea and should continue.

Monitoring

Monitoring how the township is doing in meeting its primary stewardship goal for the natural areas, increasing the diversity of native vegetation at Harriet Wetherill Park, is important. There are a number of potential methods for stewardship tasks like invasive removal. Without monitoring, the township will not know which methods are worth continuing and which are not.

Monitoring also takes time, planning, and good communication among staff. Fortunately, HWP does not need scientifically rigorous monitoring (of the sort that the U.S. Forest Service does, for example) to get a general understanding of how the park is faring. A simple way to monitor the effectiveness of stewardship efforts would be through photographs and written descriptions plus a record of what was done, when it was done, and where it was done (Jones Sauer 1998).

To monitor vegetation changes over time, first Plymouth Township needs to establish a baseline – an inventory for the site as it is now, prior to beginning new management tasks. This report provides much of the baseline information necessary, including a species inventory, verbal descriptions, and photographs of the park.

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NOTES

Personal communication with the following people was immensely helpful in preparing this stewardship plan:

Beerley, T. Natural Areas Horticulturist, the Morris Arboretum of the University of Pennsylvania. Tracy provided feedback on the management tasks and schedule for HWP.

Block, T. John J. Willaman Chair and Director of Botany, the Morris Arboretum of the University of Pennsylvania. In addition to performing the plant species inventory, Tim provided input on indices used that could be used to assess diversity of vegetation and commented on a draft of this plan.

Low, S. Biological Scientist, Philadelphia Field Station, U.S. Forest Service. Sarah advised on which tasks at HWP to undertake first and on strategies for organizing groups of volunteers. She also provided recommendations on invasive removal techniques and use of cover crops after disturbing the soil through mechanical removal.

Marrocco, V. Chief Horticulturist, the Morris Arboretum of the University of Pennsylvania. Vince informed me of the regulations and licensing requirements for applying pesticides to public land.

Rhodes, L. Restoration Field Supervisor, Urban Forestry and Ecosystem Management, Philadelphia Parks & Recreation. Luke discussed methods that Philadelphia Parks and Recreation uses to protect new plantings from deer browse.

Appendix A: Management Tasks for HWP by Stewardship Unit

ACTIVITIES	STEWARDSHIP UNITS							Who will do this?
	Ridge Woodland	Wet Woodland	Riparian Woods	Hedgerows	Wet Meadow	Woody Meadow	Butterfly Garden	
Removing Plants								
Remove invasive/exotic shrubs				X		**X**		Volunteers
Control poison ivy along trails						X		Park staff
Remove garlic mustard and stiltgrass	**X**							Park staff
Cut vines in trees				**X**				Volunteers
Remove invasive ornamentals						X	X	Volunteers
Remove Japanese honeysuckle vines	**X**					**X**		Volunteers
General weeding							X	Volunteers
Improving Soil								
Close off 'rogue' footpaths		**X**	**X**		**X**			Volunteers
Add leaf litter and woody debris				X				Volunteers
Plant bottlebrush grass to protect soil in disturbed areas	X			**X**				Volunteers
Remove 'rogue' organic dump sites				**X**				Volunteers
Mitigate trail erosion		X						Volunteers
Mulching							X	Volunteers
Protecting People								
Monitor for hazardous trees along trails	X	X	X	X				Certified arborist
Keep trails clear of debris and encroaching vegetation	X	X	X	X		X		Volunteers
Protecting Plants								
Flag spring ephemeral plants	X							Botanist or knowledgeable plantsman
Install deer fencing and inspect regularly	X	X						Park staff
Use deer repellant or fencing to protect new trees		**X**	**X**					Park staff
Adding Plants								
Plant deciduous trees (early successional)			X	X				Volunteers or contractors
Plant edge buffers				**X**				Volunteers or contractors
Plant evergreens						X		Volunteers or contractors
Plant sedges		X			X			Volunteers
Plant shrubs				X				Volunteers

Note 1: all activities labeled 'Volunteers' could also be done by park staff if desired
Note 2: all activities labeled 'Volunteers' need a coordinator to schedule, instruct, direct, provide tools, etc.
X = highest priorities

TITLE: **COMPOST PROGRAM AT THE MORRIS ARBORETUM**

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The Alice & J. Liddon Pennock, Jr. Endowed Horticulture Intern

DATE: **May 2013**

ABSTRACT:

The importance of composting has been highlighted over the years, due to the large array of resulting benefits. Specific environmental conditions are essential to optimize microbial communities within the compost pile, which dictates overall compost health. The Morris Arboretum has been unable to maintain these conditions under the current composting system; therefore, producing a low quality product.

In 2011, the Morris Arboretum received a University of Pennsylvania Green Fund Grant to implement a Sustainable Landscape Management program. Through this program, a compost tea initiative was started that relies on quality compost to produce maximum results. To help continue with this initiative, I have developed a small scale composting system at the Arboretum separate from the current system. The goal is to create small quantities of high quality compost specifically for use in the compost tea project.

In order to evaluate the success of the project, Rodale Institute and Pennsylvania State University will be testing the compost. This includes the original compost being made, along with the subsequent batches produced after the new management plan is put into effect. The quality assessment is based on both the microbiology and the general characteristics of the compost.

Compost Program at the Morris Arboretum

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INTRODUCTION

The importance of compost has been extensively talked about in the gardening realm, along with the horticulture community as a whole. Compost provides a wide range of benefits including: promoting healthy plant growth, improving soil structure, and reducing waste. "Composting is a process that allows naturally occurring microbes to convert yard waste, such as leaves and grass clippings, to a useful organic soil amendment or mulch" (Brown 2009). Therefore, the production of quality compost is dictated by the microbial communities present within the system. Beneficial soil microbes not only increase soil fertility and health, but improve nutrient availability for plants, promote growth, and reduce the impact of pests and pathogens (Dixon 2012). By maintaining favorable conditions to maximize these organisms, the Morris Arboretum can ensure the production of high quality compost.

The use of organic fertilizers such as compost goes back centuries. The Akkadian Empire in Mesopotamia referenced the use of compost for agricultural purposes on clay tablets 4,500 years ago in 2350 BCE. Since then compost has been seen in every major civilization including the Romans, Egyptians, and Greeks (Thomsen 2002). Marcus Cato, a Roman Statesman wrote a book entitled De Agri Cultura, which outlines the importance of soil fertility with a focus on the economics of agriculture. He highlighted the use of compost, and that was 2,000 years ago. In the 1800s George Washington Carver was an important advocate for compost stating "make your own fertilizer...compost can be had with little labor and practically no cash outlay" (Minneapolis Department of Public Works 2013). More recently, in 1931, Sir Albert Howard, an English botanist and organic farmer, published a book entitled, "The Waste Products of Agriculture: Their Utilization as Humus." In the book, special attention was given to the heating phase, carbon-nitrogen ratios, the importance of aeration, and the need to keep materials moist in the composting process (Saskathewan Waste Reduction Council 2005). Howard's ideas formed the foundation of modern composting practices and today he is known as the Father of Compost.

Compost was the most widely used form of fertilizer until a German scientist named Justus von Liebig started researching plant nutrients. He was able to prove that "plants obtained nourishment from certain chemicals in solution," after which, he dismissed the importance of compost because it was insoluble in water (Friend 2013). This discovery increased the concentration on chemical use in agriculture fields to increase crop production. Today Justus von Liebig is known as the Father of the Fertilizer Industry.

Currently the focus seems to be shifting back to more organic alternatives due to some negative impacts of inorganic fertilizers. The difference between organic and inorganic fertilizers is that organic fertilizers are made up of natural ingredients from plants and animals, while inorganic fertilizers are manufactured from minerals or synthetic chemicals (Lenahan 2013). The environmental impacts of these synthetic chemicals have caused many unforeseen problems. Plants are unable to absorb all the nutrients provided in the fertilizer before it begins to leach out of the system, causing pollution of waterways. All inorganic fertilizers focus on nitrogen, phosphorus, and potassium content. The nitrogen in fertilizer appears to be of most concern in environmental issues. Increased nitrogen in the water causes excessive algae blooms, reducing the available oxygen within the water, leading to fish mortality (Perlman 2013). Soil

acidification, high cost, fertilizer dependency, and a lack of long-term sustainability on the landscape, are just a few of the major remaining problems produced by inorganic fertilizers.

In recent years, compost tea has become increasingly popular within the horticulture community. Compost tea is simply a brewed, water extract of compost, which concentrates the soil microbes found within a compost pile into water-based application (Ingham 2005). Essentially, finished compost is collected and placed within a large tea bag and aerated in a multi-gallon brewer filled with water. As the water is aerated, the micro-organisms come into suspension and multiply quickly due to the high concentrations of oxygen. Additives such as fish extract are added to the brewing process as a food source for the microbes, further aiding in reproduction. The major benefit of compost tea is the little amount of compost needed to positively impact large areas within the gardens.

Once the compost tea is ready, the extract is loaded into a sprayer and then applied to the desired area. The beneficial organisms within compost tea are then transferred to the foliage of the plants or the soil where the plants are growing. Once there the micro-organisms bind to the leaf and root surfaces, allowing no room for disease and other pathogens to infect the plants.

Public gardens have a unique opportunity to experiment with management techniques and educate the community about new improvements being discovered. The Rose Garden at the Arboretum recently changed to an organic management plan by using compost tea instead of chemical fertilizers. In 2011 the Morris Arboretum received a University of Pennsylvania Green Fund Grant to implement a Sustainable Landscape Management program. Through this grant, the Arboretum was able to purchase a compost tea brewer and other necessary equipment to start the new management program. Compost tea has been used in the Arboretum's Rose Garden for the past two years and has recently been added to the Azalea Meadow and the turf management practices around Widener. The compost currently being used to make compost tea is not the best, which limits the amount of good it can do for the plant and the soil. Therefore, the purpose of my project is to create high quality compost for use in the compost tea program.

CURRENT SYSTEM

The Arboretum currently works in partnership with Springfield Township to maintain a composting facility on the Bloomfield Farm property. All of the natural debris removed from the Arboretum's landscape is collected and placed in a pile on the northwest side of the farm. In the fall, all the Township's leaves are transported here and ground, along with the Arboretum's debris created over the year. Springfield Township owns a tub grinder, which makes the process move quickly. After the material is ground and formed into windrows, it is left over the winter to decompose. In the spring a majority of the leaf mulch is distributed throughout the Township, while the rest is left for use within the Arboretum.

This is a low maintenance system; however, low quality compost is created. The piles are not being properly aerated, causing lower numbers of beneficial micro-organisms as well as a non-uniform end product. Without the windrows being turned regularly, all the debris is not

guaranteed to reach the middle of the pile. The high temperatures experienced in the center of the pile are required to kill the undesirable pathogens along with the weed seeds present in the debris. This past year I noticed a Bobcat repeatedly driving over huge piles of ground debris in order to make the stacks higher, completely compacting the material underneath. This decreases pore space, which decreases the availability of oxygen and water within the system. Without enough oxygen and water the micro-organisms within the decomposing material will also suffer.

Presently, the Township and the Arboretum do not have the time or the staff to dedicate to the proper management of a large scale compost facility. Unfortunately, not only is time a factor when running a compost site, but also having the proper equipment is vital. Currently there is no turner for the compost piles and without this critical piece of machinery, large amounts of quality product cannot be created. Hopefully in time, the necessary equipment will be obtained and there will be better coordination with Springfield Township to make sure that all the compost being made is high quality.

CASE STUDIES

Over the course of researching compost and production alternatives, I visited two local public gardens to observe their methods. Tom Brightman of Longwood Gardens and Nicole Shelby from The Scott Arboretum were gracious enough to show me around their compost facilities and answer any questions. Both facilities generate high volumes of compost for top dressing and use in their compost tea operations. Although my project is on a smaller scale than these public gardens, they provided me with a look at what the compost facility at the Morris Arboretum could become in the future.

Longwood Gardens has been composting since the 1990's and currently has an On-Farm Composting Permit from the Pennsylvania Department of Environmental Protection. This large scale operation allows Longwood to collect all of its horticultural waste products and recycle them back onto the property as compost, mulch, and field soil amendments. The onsite dining services, known collectively as The Terrace, also contribute materials to the compost that is created at Longwood. Compostable plastic silverware and vegetable scraps are all incorporated into the compost. Horse manure is the final component included in the compost and is brought in from local farms throughout the year. Due to the manure's high nitrogen concentration, it acts as a catalyst to jumpstart the microorganisms within the pile, initiating decomposition.

Longwood starts with separate piles of green waste, brown waste, and horse manure at the composting site where collection occurs during the season. Once a year Longwood rents a tub grinder to break up the large pieces of debris and mix them together. The ground materials are then placed into windrows, where they are marked with the start date and the recipe used to make up the pile. The temperature is monitored within the pile, and turning is dictated by these readings.

The Scott Arboretum of Swarthmore College, like Morris, shares their composting site with the local township. The Scott Arboretum sets aside materials to create their own compost separate from that of the township's. Every October, the township collects leaves all through the

neighborhoods, depositing them on the concrete pad owned by Swarthmore College. The leaf piles are then shaped into windrows where they are turned and shredded by the township's equipment at undefined intervals. Turning times are primarily based on weather conditions and employee availability, rather than a set schedule. The leaf mulch is then sold back to the township in early April.

Once there is free space on the concrete pad, the mixed garden debris that Scott Arboretum has been collecting over the season, as well as some dining hall waste from the college, is moved onto the platform. The township then turns the Arboretum's compost periodically. The temperature is checked frequently by Arboretum staff to make sure the pile is staying between 130°F and 160°F to kill the weed seeds and detrimental microorganisms; however, turning is not dictated by temperature. Compost turners are expensive pieces of equipment that not many medium sized compost facilities can afford to purchase. Therefore, the township and Swarthmore College have reached an agreement, exchanging compost facility space for turner privileges.

The finished compost is then used all over the Scott Arboretum; including the intensive organic lawn section, where the lawn is top dressed with compost and routinely sprayed with compost tea as the management regime. The Scott Arboretum has been trained by Dr. Elaine Ingham from The Rodale Institute on compost production and compost tea application methods. Regular checks are conducted for micro-organisms under the microscope in order to determine compost health.

METHODS

Many different composting systems have been created over the years. Large commercial scale and small backyard operations are prevalent, but medium sized options do not seem to have a niche. When first proposing my project, I intended to apply to the University of Pennsylvania's Green Fund Grant with the goal of buying the Arboretum its own tub grinder. The creation of a medium scale operation was the hopeful outcome. After writing up a proposal, going over whether to include Springfield Township and the Compton Café into the plans, and what the real goal for my project was, applying for funding was not the logical option.

The Arboretum having its own grinder would be ideal if there was the staff and space to create a large scale composting facility. With the onset of such an extensive operation, the need arises to purchase more machines in order to turn the massive piles, which at this time is not feasible. The main goal of my project is to help create small amounts of quality compost to use in the production of compost tea. So we decided to retrofit a small backyard operation into something that could work at the Arboretum.

Large tumblers seemed like a good option, minimal effort is required once the material is compiled and turning the compost within the drum is a simple turn of the crank. Upon further review, tumblers are difficult to maintain at a specific moisture content and often become water logged. When the moisture becomes too high the compost can become anaerobic, which ruins

the product. Simple wire fencing looped and attached with bungee cords was a cheap alternative; however, turning the pile is not ideal.

The final method considered was the 3-bin compost system, popular in homeowner backyards and smaller gardens. The wooden bins account for space to turn the compost and compartments to let it mature. The system is stationary, strong, and a simple design. Turning the pile will be easier due to the wooden slats in the front of the bins that can be removed for access. These slats, as well as the wire mesh for sides, will facilitate air flow through the piles, helping aid decomposition. All in all this system was the best option for the Arboretum.

Deciding on building materials for the compost bin is an important consideration that should not be overlooked. Leaching was a main concern when constructing the bins. Treated lumber is never appropriate to build with due to the harsh chemicals used to preserve the wood. Leaching from this lumber includes chemicals like arsenic and copper, both a cause for alarm. Naturally decay resistant wood is a good choice for building material, the main drawback being the high price. Composite plastic lumber was another choice considered for the bins. The manufacturers claim no leaching occurs and it lasts a long time, the main drawback is again the cost. For the compost bins at the Arboretum, I have chosen to use Douglas fir lumber, which is somewhat decay resistant, but cheaper than other wood like cedar. Douglas fir is also readily available in local hardware stores, so finding the material was convenient.

The usual bin system is made up of three separate bins, each 3ft x 3ft x 3ft in size. This volume is the minimum size requirement needed in order to reach the high temperatures necessary to eliminate the unwanted seeds and disease causing pathogens within the compost pile. For the purpose of my project, I have decided to construct a four bin system. Using the Cornell Waste Management Institute's three bin system as a template (See Figure 1), an additional 3 ft^3 bin was built. The extra bin will allow ample room for turning and storage of the compost once it is ready for use.

Deciding where to place the compost bins once contracted was another major consideration. Ease of access was a main concern, which is why one of the cinderblock bins near the current compost site at Bloomfield Farm was chosen. The only drawback was the presence of a few the walnut trees near the site. Walnut trees produce a chemical known as juglone, which inhibits the growth of other plants in the area. All the cinderblock bins were checked for debris, mainly seeds, from the walnut trees. After careful inspection the two bins furthest from the trees were clean, while the other two bins contained some nuts. The furthest bin was chosen in order to be safe and it was a little larger than the others.

Some compost bins include a wooden base; however the concrete bin where the compost system was placed served as a manufactured bottom. When a compost pile is put together, all the material is added at one time to ensure the whole pile is finished decomposing at the same time. If new material is added after the process has already started, one cannot be sure which part of the pile is finished and which part has yet to fully decompose.

MANAGEMENT PLAN

The beneficial micro-organisms present in compost require oxygen, water, and food in order to survive and reproduce. The natural materials that make up the compost pile provide the necessary food, while regularly monitoring the temperature and moisture content within the pile will ensure the presence of the others.

The most important task in compost management is proper aeration. Once the pile becomes anaerobic, the beneficial organisms die, ridding the compost of its beneficial qualities. Checking the temperature of the compost daily will help determine what is happening within the pile and ultimately dictate when it has to be turned.

The temperature is driven by the micro-organisms. The hotter the pile, the more active the microbes are. Once the pile reaches a certain temperature, it needs to be turned in order to incorporate more oxygen back into the system. The compost pile only needs to be at 160°F for one day, 150°F for two days, or 131°F or above for three days in order to remove the organisms and seeds that are not beneficial from the center of the pile (Ingham 2012). Once those conditions have been reached, the pile needs to be turned to incorporate the untreated compost into the center of the pile, and so on. Each time the pile is turned you must make sure the temperature is reached. The compost will be ready once the pile no longer reaches these high temperatures.

The compost bins constructed for this project are well exposed to the outside environment, helping the movement of oxygen into the system. The sides are made of galvanized ½ inch wire fencing, sturdy enough to hold the compost in the bin, but open enough for proper ventilation. A width of three feet will be maintained between the compost bins and the cinderblock wall housing the system. This will allow further air circulation and the ability to collect materials we may lose while turning the compost.

The recommended moisture content to maintain within the compost pile is about 50%. There are many expensive devices on the market that take moisture content readings, but a much similar method may be employed for taking readings of the compost here at the Arboretum. While attending a Composting Basics Class at the Rodale Institute, Dr. Ingham taught a quick and basic test that requires only your hand. Dig into the pile and take a handful of compost, squeeze the material as hard as you can and only 1-2 droplets should come out. If there are more drops the moisture content is too high, and if there are no drops it is too low. If the there is too much moisture, turn the pile to add some air into the system to aid in drying the material. If the pile is too dry, add some water using a hose.

Where the compost tea will be spread determines how to compose the compost pile. A high fungi-to-bacteria ratio is necessary for both the Rose Garden and turf areas; therefore, a higher amount of woody materials, such as woodchips, will be incorporated into the compost recipe. A recipe recommended by the Rodale Institute is a 60% brown, 30% green, and 10% high nitrogen material. When constructing the pile, add materials following a layer pattern, alternating the brown, green, and high nitrogen. Once the bin is filled, remove the front slats for easy access

to the pile. Using a pitchfork, transfer the pile into the next bin mixing and watering the material as it is moved. This will ensure a well-mixed compost pile with proper moisture content.

During the compost tea brewing process, fungal foods such as algae extract should be added to encourage the fugal growth within the tank. During the compost tea application, fungal strands suffer a loss, due to the pressure of the sprayer and size of the nozzle. Larger nozzles should be used to make sure these important organisms are not torn apart during application. This is another reason to bulk up the fungal numbers both when making the compost and during the brewing process.

RESULTS

In order to determine if the new compost created for the compost tea program is higher quality, soil tests were done. In September I collected soil samples from the compost created by the township and sent them to the Rodale Institute and Pennsylvania State University. The Rodale Institute offers the unique opportunity to test the life of the soil. Bacterial and fungal counts, along with nematode numbers and protozoa concentrations were reported (Table 1). Pennsylvania State University performs a standard soil test, reporting on pH levels, cation exchange capacities, and macro-nutrient levels (Table 2). We also ordered additional tests to determine the percentage of organic matter and micro-nutrient concentrations in the compost (Table 3).

According to the Rodale test, there are plenty of bacteria within the compost; however, there are virtually no fungi or protozoa present. Without the presence of these micro-organisms, the compost is of low quality and the compost tea being brewed will not greatly benefit the plants. Other than the lack of proper aeration in the current composting system, there is also a lack of material diversity. About 90% of the material used to create the compost is leaves. The lack of soil life reflects the lack of diversity represented in the compost piles.

After all the preliminary research was conducted, I set-up a compost pile in the beginning of March. I alternated layers of green and brown waste and then mixed the pile well with a pitch fork while adding watering. The temperature was monitored daily, and after a week, the high temperatures needed to kill the undesirable seeds and pathogens had not been reached. Milorganite, an organic fertilizer, was then added on the 8th day as a high nitrogen source to boost the metabolism of the beneficial micro-organisms within the compost pile. Within a few days the high temperatures required were reached and the pile was then turned (Figure 2).

Due to time constraints, the first batch of compost will not be ready prior to the end of the internship. Soil testing will need to be done after the new compost is complete to determine if this compost system is an effective approach to making quality compost for the compost tea program.

FUTURE STEPS

In the future, there are several advances that the Arboretum should follow regarding compost. There needs to be more collaboration between Springfield Township and the Arboretum. With the current system in place to make compost specifically for compost tea, this does not solve the overall problem of low quality compost being used throughout the township and within the Arboretum as top dressing. By purchasing a compost turner, the quality of the product will vastly improve. This will allow the windrows to be properly aerated.

The sheer amount of debris brought in by the township is also too large for the space available at Bloomfield Farm for composting. This is an important consideration when moving forward into solving the larger issues faced by the Arboretum.

Even though the compost being created by Springfield Township is not the best quality, it can be made better by managing the weeds that grow in Bloomfield Farm around the area of the pile. By eliminating one potential seed source, this will reduce the amount of weed seeds being introduced into the Arboretum through the leaf mold.

The creation of a closed system for handling waste in the Arboretum is an admirable goal. Therefore, incorporating the food waste from Compton Café is another goal to strive for within the Arboretum. This system will set a wonderful example for all public gardens, as well as, create a teaching opportunity for the community.

ACKNOWLEDGEMENTS

I would like to thank the entire Horticulture Staff for their support and guidance on my project, especially my supervisor, Chief Horticulturist, Vince Marrocco. I would also like to thank Tom Brightman from Longwood Gardens and Nicole Shelby from the Scott Arboretum for giving me a tour of their compost facilities and answering my questions.

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TABLES AND FIGURES

Table 1. The initial Rodale Institute compost test results for the life in the soil.

Sample	Total Bacteria (micrograms/ gram)	Total Fungi (micrograms/gram)	Protozoa (numbers of flagellates and amoebae)	Nematodes (numbers of majors groups observed)
1	1395 158 Actino	0	48000 F 16000 A	0
2	3021 158 Actino	132	16000 F 32000 A	0

Table 2. The initial Pennsylvania State University compost test results.

			Exchangeable Cations (meq/100g)					% Saturation of the CEC		
Sample	pH	Mehlich 3 (ICP)	Acidity	K	Mg	Ca	CEC	K	Mg	Ca
1	8.4	410	0	4.3	13.4	23	32.7	13.1	41	45.9
2	8.6	398	0	5.24	15.23	23.87	35.5	14.8	42.9	42.3

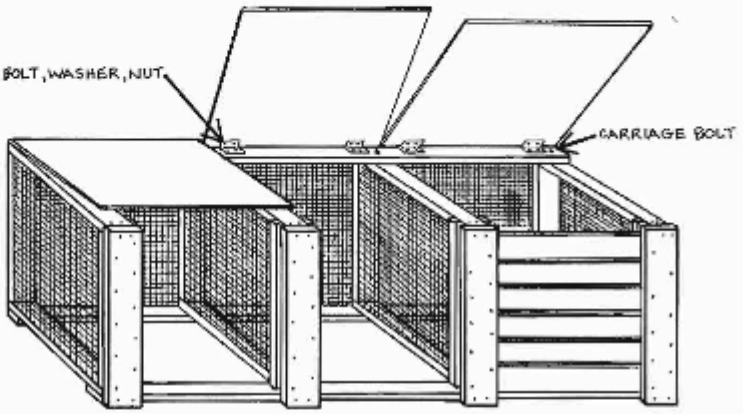
Table 3. The initial Pennsylvania State University additional test results for compost.

Sample	Organic Matter %	Copper (mg/kg)	Iron (mg/kg)	Manganese (mg/kg)	Zinc (mg/kg)
1	26.2	2.44	221.53	55.9	25.56
2	30.1	2.19	231.22	53.43	21.83

Figure 1. Compost bin design.

Wood and Wire Three-Bin Turning Unit

A wood and wire three-bin turning unit can be used to compost large amounts of yard, garden, and kitchen wastes in a short time. Although relatively expensive to build, it is sturdy, attractive, and should last a long time. Construction requires basic carpentry skills and tools.



What You Need

Materials

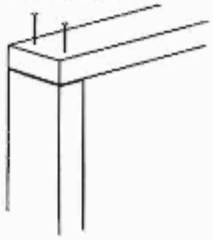
- 4 12-foot (or 8 6-foot) lengths of pressure-treated 2 x 4 lumber
- 2 10-foot lengths of pressure-treated 2 x 4 lumber
- 1 10-foot length of construction grade 2 x 4 lumber
- 1 16-foot length of 2 x 6 lumber
- 6 8-foot lengths of 1 x 6 lumber
- 1 4-x-8-foot sheet of 1/2-inch exterior plywood
- 1 4-x-4-foot sheet of 1/2-inch exterior plywood
- 22 feet of 36-inch-wide 1/2-inch hardware cloth
- 2 pounds of 16d galvanized nails
- 250 poultry wire staples (or a power stapler with 1-inch galvanized staples)
- 12 1/2-inch carriage bolts 4 inches long
- 12 washers and 12 nuts for the bolts
- 6 3-inch zinc-plated hinges
- 24 washers and 24 nuts for the hinges
- 1 quart wood preservative or stain

Tools

- tape measure
- hand saw or circular power saw
- hammer
- tin snips
- carpenter's square
- optional: power stapler with 1-inch galvanized staples
- drill with 1/2-inch bit
- screwdriver
- 3/4-inch socket or open-ended wrench
- pencil
- safety glasses
- ear protection
- dust mask
- work gloves

Building a Wood and Wire Three-Bin System

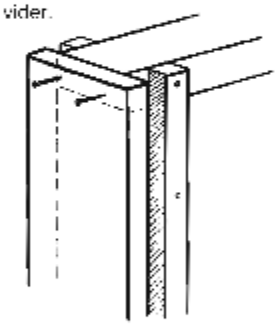
1. Cut two 31 1/2-inch and two 36-inch pieces from a 12-foot length of pressure-treated 2 x 4 lumber. Butt joint and nail the four pieces into a 35-inch x 36-inch "square." Repeat, building three more frames with the remaining 12-foot lengths of 2 x 4 lumber.



2. Cut four 37-inch lengths of hardware cloth. Fold back the edges of the wire 1 inch. Stretch the pieces of hardware cloth across each frame. Make sure the corners of each frame are square and then staple the screen tightly into place every 4 inches around the edge. The wood and wire frames will be dividers in your composter.

continued on next page

3. Set two dividers on end 9 feet apart and parallel to one another. Position the other two dividers so they are parallel to and evenly spaced between the end dividers. The 36-inch edges should be on the ground. Measure the position of the centers of the two inside dividers along each 9-foot edge.
4. Cut a 9-foot piece from each 10-foot length of pressure-treated 2 x 4 lumber. Place the two treated boards across the tops of the dividers so each is flush against the outer edges. Measure and mark on the 9-foot boards the center of each inside divider.
5. Line up the marks, and through each junction of board and divider, drill a 1/2-inch hole centered 1 inch in from the edge. Secure the boards with carriage bolts, but do not tighten them yet. Turn the unit so the treated boards are on the bottom.
6. Cut one 9-foot piece from the 10-foot length of construction grade 2 x 4 lumber. Attach the board to the back of the top by repeating the process used to attach the base boards. Using the carpenter's square or measuring between opposing corners, make sure the bin is square. Tighten all the bolts securely.
7. Fasten a 9-foot length of hardware cloth to the back side of the bin with staples every 4 inches around the frame.
8. Cut four 36-inch-long pieces from the 16-foot length of 2 x 6 lumber for front runners (Save the remaining 4-foot length.) Rip cut two of these boards to two 4 3/4-inch-wide strips. (Save the two remaining strips.)
9. Nail the 4 3/4-inch-wide strips to the front of the outside dividers and baseboard so they are flush on the top and the outside edges. Center the two remaining 6-inch-wide boards on the front of the inside dividers flush with the top edge and nail securely.
10. Cut the remaining 4 foot length of 2 x 6 lumber into a 34-inch-long piece and then rip cut this piece into four equal strips. Trim the two strips saved from step 8 to 34 inches. Nail each 34-inch strip to the insides of the dividers so they are parallel to and 1 inch away from the boards attached to the front. This creates a 1-inch vertical slot on the inside of each divider.



11. Cut the 6 8-foot lengths of 1 x 6 lumber into 18 slats, each 31 1/4 inches long. Insert the horizontal slats, 6 per bin, between the dividers into the vertical slots.
12. Cut the 4-x-8-foot sheet of exterior plywood into two 3-x-3-foot pieces. Cut the 4 x 4-foot sheet of exterior plywood into one 3-x-3-foot piece. Center each 3-x-3-foot piece on one of the three bins and attach each to the back top board with two hinges.
13. Stain all untreated wood.

Adding Wastes

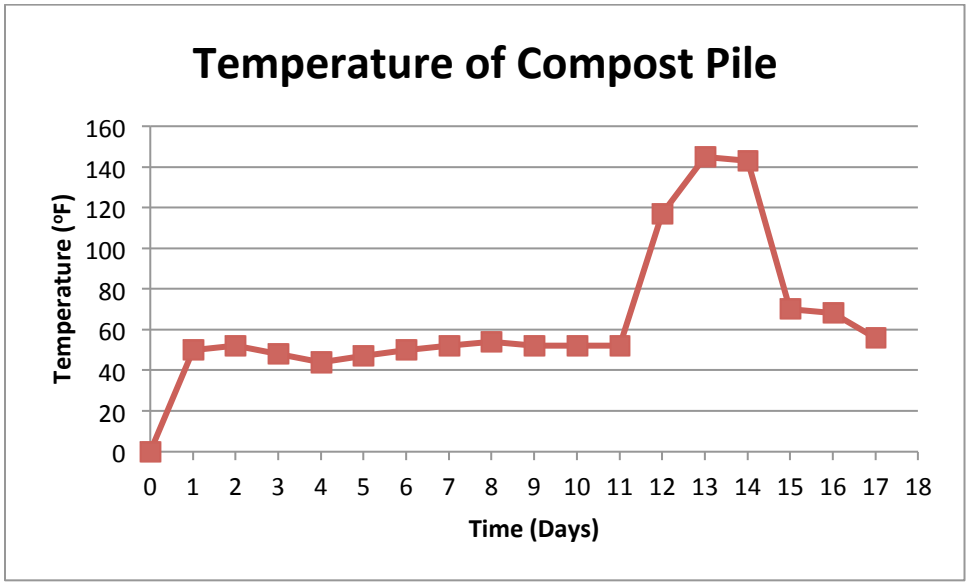
Do not add wastes as they become available with this system. Collect enough wastes to fill one of the three bins at one time. You can collect woody as well as nonwood wastes. Add thin layers of different kinds of organic materials or mix the wastes together.

Before adding new wastes to an empty bin, collect enough to fill the entire bin.

Maintaining Your Compost Pile

Take the temperature of your pile every day. After a few days, the temperature should reach between 130° and 140°F (54° to 60°C). If your pile gets very hot, turn it before the temperature gets above 155°F (68°C). In a few days, the temperature will start to drop. When the temperature starts going down, turn your compost pile into the next bin with a pitchfork. The temperature of your compost pile will increase again and then, in about four to seven days, start to drop. Turn your compost pile into the third bin. The total time for composting should be less than one month.

Figure 2. Daily temperature of newly created compost pile.



TITLE: **MORE KIDS IN THE WOODS: MORRIS ARBORETUM AS OUTDOOR LABORATORY**

AUTHOR: **Sarah Bolivar**
The McLean Contributionship Endowed Education Intern

DATE: **March 2013**

ABSTRACT:

The Morris Arboretum, a 92-acre historic public garden and educational institution, seeks to enhance people's awareness of their interdependence with plants. To support this mission, the Arboretum formed a partnership with the USDA Forest Service and developed the framework for More Kids in the Woods (MKIW) – a two-year pilot and grant-funded program intended to serve underrepresented youth in the Philadelphia region. As Education Intern, I have had the privilege to help support the first stages of the grant. In this report, I summarize the challenges, programming, and goals of MKIW. Additionally, I briefly reference the developmental stages of children's relationship to nature – as well as discuss the theory of "nature" – to provide context and acknowledge the unequal access to nature across cultures and socio-economic classes. The intended audience is anyone interested in fostering an environmental consciousness in youth and/or implementing a federal grant to achieve this purpose. It is my hope that certain initiatives will become established through the implementation of MKIW, such as an annual outdoor career symposium for high school students. Through the cumulative efforts of all department heads and financial supporters, the Morris Arboretum can begin to pave the way for educational programming that is socially, culturally, and economically inclusive.

More Kids in the Woods: Morris Arboretum as Outdoor Laboratory

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MORE KIDS IN THE WOODS STRUCTURE

In the fall of 2012, The Morris Arboretum received federal funding to implement More Kids in the Woods (MKIW), a two-year pilot program that provides resources to Title I schools in the Philadelphia region, in conjunction with the USDA Forest Service.[1] The grant is intended to serve underrepresented and underserved youth that might otherwise not have access to large-scale, open spaces.[2] By increasing access to the Morris Arboretum, students will be able to integrate their curriculum into the physical environment and vice-versa. These experiential interactions will allow students to utilize the Arboretum as an "outdoor laboratory" – a space where students can observe red-tailed hawks flying overhead, explore the dawn redwoods, and enhance their understanding of local and regional ecosystems. In this paper, I will discuss the challenges, programming, and goals of More Kids in the Woods within the context of Morris Arboretum educational programming initiatives.

Though the Morris Arboretum has an institutional mission to serve underprivileged youth through Partners in Education, the MKIW is a formal agreement among Morris Arboretum, the USDA Forest Service, and three schools: W.B. Saul High School of Agricultural Sciences, Mercy Vocational High School, and Wissahickon Charter School. The grant applicants were Liza Hawley, Visitor Education Coordinator, and Bob Gutowski, Director of Public Programs. This application was a competitive process, but the Morris Arboretum has had a successful record with the USDA Forest Service, and the two have collaborated on urban forestry projects in the past. Throughout this process, USDA Forest Service Field Station Coordinator, Sarah Low, has worked closely with Arboretum staff and educational partners. At the two-year benchmark, the Forest Service and Arboretum staff will make their findings publicly available.

"Nature" versus "nature"

To encourage a frank discussion regarding the relationship between children and the environment, I will first address a term that is not inherently fixed in meaning and which asks us to reflect on what we deem to be "natural." Nature, or rather how we perceive nature, has inevitably changed throughout the last century. No longer can we preserve a view of "pristine wilderness" as the apogee of nature. Rather, we can acknowledge the beauty and function of ecosystems within highly built environments to embody our social construct of nature. The definition can be infinitely expanded upon, but the point I want to emphasize is that though "nature" and "natural" are interlinked conceptually and etymologically, we must not forget that urban environments, which 70% of the world population is expected to inhabit by 2050, fit within this framework as well.[3] Addressing this issue – helping students understand they can apply what they learn at the Arboretum to their own built environments – will help empower

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[1] "**USDA Forest Service Makes $1 Million Commitment to Get Kids Outdoors**." US Forest Service. Web. 03/2013.
<http://www.fs.fed.us/news/2012/releases/03/kids.shtml>.

[2] "Open Space Conservation." United States Department of Agriculture Forest Service. Web. 03/2013.
<http://www.fs.fed.us/openspace/>.

[3] "Human Population: Urbanization." Population Reference Bureau. Web. 03/2013.
<http://www.prb.org/Educators/TeachersGuides/HumanPopulation/Urbanization.aspx>.

students to be proud of their communities and enable them to promote environmental conservation practices at local, regional, and global scales.

Writer Neil Evernden distinguishes between "'nature' when referring to the great amorphous mass of otherness that encloaks the planet" and "'Nature' when referring specifically to the system or model of nature which arose in the West several centuries ago."[4] The latter embodies a mostly non-human cultural ideology, but this is not accurate as human beings have inhabited land throughout millennia. A corollary to this discussion is the question of access to nature. Historically, aesthetic appreciation of nature has been restricted to white middle and upper classes while citizens in lower-income brackets and/or people of color have been susceptible to subtle forms of exclusion. [5,6] In a rapidly changing social landscape, where Philadelphia's projected population growth will largely stem from non-white residents,[7] collecting, analyzing, and sharing data about these demographic trends will become a prominent issue for arboreta and public gardens.

Through the MKIW grant and Partners in Education, the Morris Arboretum has formally begun to recognize and address disparity across the socio-economic spectrum. To further shed light on the populations we serve, it would be beneficial for the Arboretum to undergo an in-depth analysis of the needs and demographics of the visiting youth population; lead and participate in civic dialogues regarding public garden's growing social roles; and invest in an internal task force charged with attracting diverse populations to the Arboretum.

Children's Values of Nature and Programmatic Context

To help contextualize the Arboretum's varied educational programming, it is useful to examine children's values of nature across their developmental stages.[8] Studies suggest that the first developmental stage occurs between three and six years of age, during which children crave security. Thus, they generally appreciate familiar surroundings but can exhibit indifference or anxiety in the presence of unfamiliar environmental stimuli.[9] Through our partnership with Wissahickon Charter School, we have been able to schedule visits with 136 pre-k and kindergarten students. Generally, the students went on self-guided or Seasons and Cycles tours.

The middle school age, when the child is six to twelve years old, is a critical and formative period as children's regard of nature changes from a sense of wonder to a sense of exploration. During this time, "humanistic, symbolic, aesthetic, and knowledge components of the scientific value develop most rapidly, while utilitarian, negativistic, and dominionistic

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[4] Adamson, Joni, Evens, Mei Mei, and Stein, Rachel. Eds. *The Environmental Justice Reader: Politics, Poetics, and Pedagogy*. (Arizona: The University of Arizona Press, 2002), 182.

[5] Adamson, Evans, and Stein. Eds., 151.

[6] "Demographic Transformation and the Future of Museums." The American Association of Museums. 2010. Web 03/2013. <http://www.aam-us.org/docs/center-for-the-future-of-museums/demotransaam2010.pdf?sfvrsn=0>.

[7] **"Demographic Trends and Forecasts in the Philadelphia Region Key Findings."**

[8] Kahn, Peter H., and Kellert, Stephen. *Children and Nature.* Eds. (Cambridge: The MIT Press, 2002), 132.

[9] Kahn and Kellert. Eds., 132.

perspectives diminish in importance."[10] This information, if accurate for all children, is important since the More MKIW program has yet to inspire firm commitment from 6th and 7th grade classes to visit on a consistent basis, funding availability notwithstanding.

Despite a gap in reaching 6th and 7th grade, we have been able to cumulatively host 239 pre-k - 6th grade students during the first six-month period of the grant. Additionally, in October, Morris Arboretum interns were able to develop and teach environmental-related lessons, such as forest succession, to nine Wissahickon Charter School classes between 1st and 6th grades. All the interns provided positive feedback, though they wished there had been a sequential opportunity to link the interns' work with their lesson at the Arboretum. [This comment is being taken into consideration and will potentially become a reality in the second six-month period of the grant].

Though the Pennsylvania School for the Deaf is not a formal MKIW partner, we have provided learning opportunities with the USDA Forest Service to 6th and 7th graders. For example, Sarah Low has led a small group around the Wetland on a bi-monthly basis to help them observe seasonal changes, learn more about wetland benefits, and study ecosystem dynamics. Students have expressed their enthusiasm for these sessions and it has personally been a rewarding experience to work with the deaf and hard of hearing population.

The final stage in children's development occurs between 13 and 17 years of age. This is a time during which children can understand more "abstract, conceptual, and ethical reasoning about the natural world."[11] The majority of our work with this age group takes place in form of specialized educational programming. In the next section, I describe these various partnerships and programs.

Cultivating Partnerships and Learning Process

Rachel Carson poignantly remarked, "For the child . . . it is not half so important to *know* as to *feel*. If facts are the seeds that later produce knowledge and wisdom, then the emotions and the impressions of the senses are fertile soil in which the seeds must grow."[12] In my role as Education Intern, I have had the good fortune to see first-hand the impact of the Arboretum's environment on visiting students. To share an anecdote, Mercy Vocational High School, a MKIW partner, brought a group of sophomores and juniors to conduct a writing exercise in the midst of the dawn redwoods. Though the students were gregarious in the beginning – as adolescents are apt to be – they began to quiet down and focus intensely on their task at hand. It was incredible to behold the students contemplating the next mark on their pages. Similarly, I have seen children's eyes open wide at the sight of wildlife or pour over their surroundings. This *feeling* is exactly what we are striving for and what is relatively easily achieved when the students get to the Arboretum. Truly, the main challenges preventing students from visiting the Arboretum are lack of school funding for buses or substitute teachers, teachers' preoccupation

[10] Kahn and Kellert. Eds., 132.
[11] Kahn and Kellert. Eds., 135.
[12] Carson, Rachel. *The Sense of Wonder*. (New York: Harper and Row, 1965).

with whether tour content aligns with state standards, and a school structure that impinges upon the teachers' sense of flexibility and creativity.[13]

Through More Kids in the Woods, we have been able to break down barriers, such as access to transportation. Since each school bus generally costs $250, teachers are grateful that we can help ease this financial burden. During the first six months, Wissahickon Charter School's pre-k and kindergarten classes visited on almost a monthly basis until we realized the MKIW grant would not be able to cover future bus expenses. This was a difficult but much-needed realization. Since then, we have begun to strategize how we can have as many age groups as possible visit the Arboretum without exhausting our transportation budget. In addition to providing transportation, we also strive to show teachers that they can apply almost any lesson plan within the Arboretum. Moreover, all our tours already meet standards of learning objectives. These barriers are all much easier to address if our partners are committed to bringing their classes on a consistent basis.

W.B. Saul High School of Agricultural Sciences is a school we have had a strong partnership with for several years. Two teachers, Barbara Brown and Jessica Naugle McAtamney, have brought their horticulture and landscape design classes to the Arboretum on a monthly basis. During these repeated field experiences, students learn about a staff member's career. Such experiences enhance students' understanding of the various career paths within the horticulture field.

We hope to have as strong a partnership with Mercy Vocational High School. Though the English class visited in early fall, other classes had not scheduled visits for fall or spring. To help teachers better understand the benefits of MKIW, we invited teachers to visit the Arboretum as part of their in-service professional development. On January 28, eleven teachers and administrative staff visited and met with Lucy Dinsmore, the Rose Garden Horticulturist, and Dianne Smith, Greenhouse and Fernery Volunteer. After this in-service event, we were able to schedule spring tours with a variety of classes. For example, different classes are scheduled to practice yoga at Bloomfield Farm, meet with Bob Gutowski to learn about non-profit management, as well as cook with our caterer.

Strong partnerships have been integral to helping us achieve our goals. If there were no partnership with the Forest Service, we would have less leverage with our school partners' support of repeated field experiences. We cannot disregard the strength of cultivating partnerships with organizations such as the Forest Service. Another factor aiding our success has been working with teachers who are both passionate and committed to providing their students with varied experiences at the Morris Arboretum. Though it is intuitive to say that arboreta should seek out partnerships, it is also equally vital to acknowledge that partnering institutions need a point person to spearhead and build momentum for collaborative efforts. Underpinning this success is also the strength of the Partners in Education Committee, comprised of staff and the Morris Arboretum Guides, which has shown unparalleled devotion to sharing its knowledge of the Arboretum.

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[13] Nagel, David. *Education System Stifles Creativity, System Finds*. The Journal. 04/2012. Web. 03/2013. <http://thejournal.com/articles/2012/04/23/education-system-stifles-creativity-survey-finds.aspx>.

Our successes have not transpired without their challenges. As I mentioned earlier, teachers lack funding to bring students to the Arboretum and are potentially unfamiliar with our tour content. Though the MKIW grant provides funding, we are only able to provide transportation subsidies to a limited number of students. To address this shortfall in funding, the Arboretum must have an internal dialogue for how it can best raise funds to cover expenses when the MKIW grant ends next year. A financially solvent model is required, but it also cannot compromise the functioning of other Arboretum programs. To address unfamiliarity with tour programming, a revamping of online content might be beneficial. We are in the process of developing a webpage that will highlight Partners in Education, a larger Morris Arboretum initiative, and MKIW as a sub-set of youth education. We hope that creating the Partners in Education page will clarify and reinforce our mission to serve the youth population.

One of the primary challenges and learning experiences has been evaluating the children's understanding of educational content. Below are some of the most pervasive challenges in regards to evaluations:

1. Education Intern has little knowledge of content evaluation practices
2. Education partners and staff have different schedules and deadlines
3. Training or guidelines for grant evaluation is not established
4. There is little time for evaluations during tours

During this process, I learned that evaluations are most successful after discussing the structure and medium with partners. For example, I learned that online evaluations work best with Saul High School and Mercy Vocational High School because students have direct access to the internet. Wissahickon Charter School, on the other hand, prefers paper evaluations because teachers have little time to reserve the computers and ask students to complete evaluations. Also, evaluations are most successful when the person most knowledgeable about the content produces and evaluates them. Despite our challenges, we are enthusiastic about the future of MKIW.

Moving Forward

Moving forward, we plan to build on two initiatives with the MKIW program. One of them is the Learning-By-Doing Tree Inventory Project, in which students conduct a tree inventory of the Saul campus through line transect sampling. Essentially, students pace out a given distance to their plots along a transect and obtain a sample of the tree population. This project will encompass skills such as basic geometry, utilizing compasses and other tools, as well as data analysis. A short-term goal is to replicate this project the following year. In the long-term, students will feel comfortable enough with these exercises that they can help conduct tree inventories within their own communities.

Another initiative is the Outdoor Career Symposium, an event during which professionals from the Philadelphia region will participate in panel discussions and lead hands-on workshops to share career and post-secondary advice with high school students. This event will enable students to explore a variety of career paths they might have not otherwise considered. Though

there are comprehensive programs promoting environmental outdoor education across the nation, there are hardly any outdoor or environmental career symposium models. Through this symposium, the Morris Arboretum will potentially create a unique public garden niche.

There have long been talks about creating a high school internship program; though this is not a goal of MKIW, our strong partnership with high schools give us the ability to work with a pool of intelligent and environmentally-conscious youth. Potentially, the Arboretum can work with the University of Pennsylvania to make this a reality through the Penn Summer High School Program.[14] As with any partnership, however, all parties need to be invested in the success and longevity of such programs.

Insights

Working on the MKIW grant has been particularly fulfilling because I enjoy working with community partners and helping youth obtain greater environmental awareness. Moreover, it's important for me to feel that I am contributing to the success of the larger community and challenging others' preconceived notions about youth from highly dense and urban environments. This experience will be beneficial as I enter the field of landscape architecture, where I will potentially apply for grants, as well as continue working with communities to address challenges through creative means. The internship experience overall has been valuable and I've learned a great deal about horticulture and the non-profit structure, which I hope to build on in the future.

Acknowledgements

I would like to thank Liza Hawley, Lisa Bailey, the Partners in Education team, Morris Arboretum Staff, the USDA Forest Service, Parks and Recreation, and our educational partners for making this a very rewarding project to work on throughout the year.

[14] *Penn Summer Academies*. 03/2013. <http://www.sas.upenn.edu/summer/programs/highschool/academies>.

Appendices

(Appendix 1)

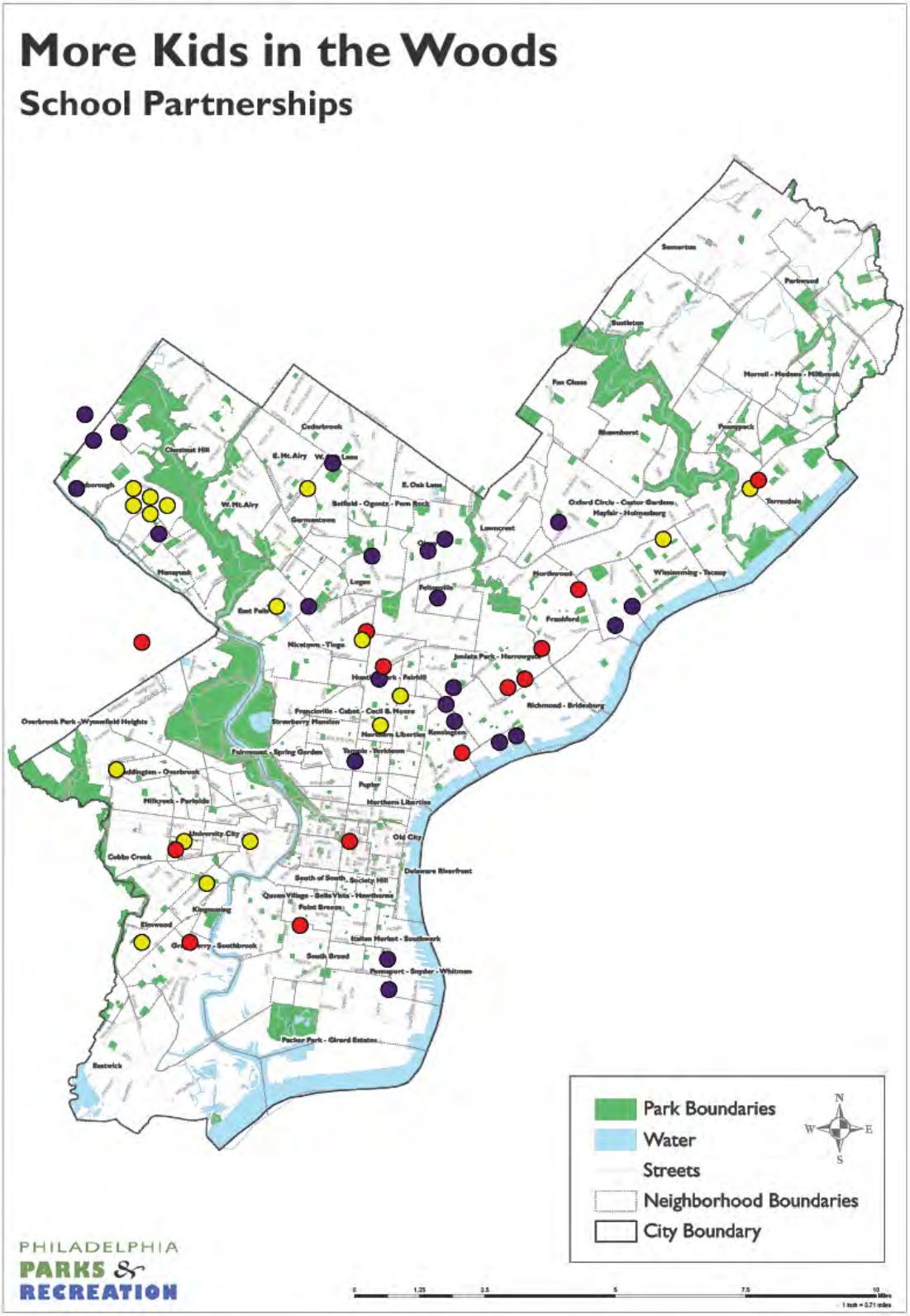
The following map, produced by Regina Stine, Parks and Recreation GIS Intern, illustrates samples of student populations from our Partners in Education schools. Students were asked to look at a map of Philadelphia's neighborhoods and place a pin on where their house is located. The map is an attempt to collect more data about the youth we serve. Part of the goal is to obtain a greater sample population and then analyze public park distribution within each neighborhood to see whether students live within a .5 mile radius of these parks. Oftentimes, educational researchers examine canopy coverage as an indicator of "access to nature," but fail to examine where students' homes are located in relation to this public park. This data, if complemented with reflections from students, could help the Morris Arboretum better understand how students perceive nature and how the Arboretum can best serve the students' needs.

Yellow Circles: W.B. Saul High School of Agricultural Sciences

Red Circles: Mercy Vocational High School

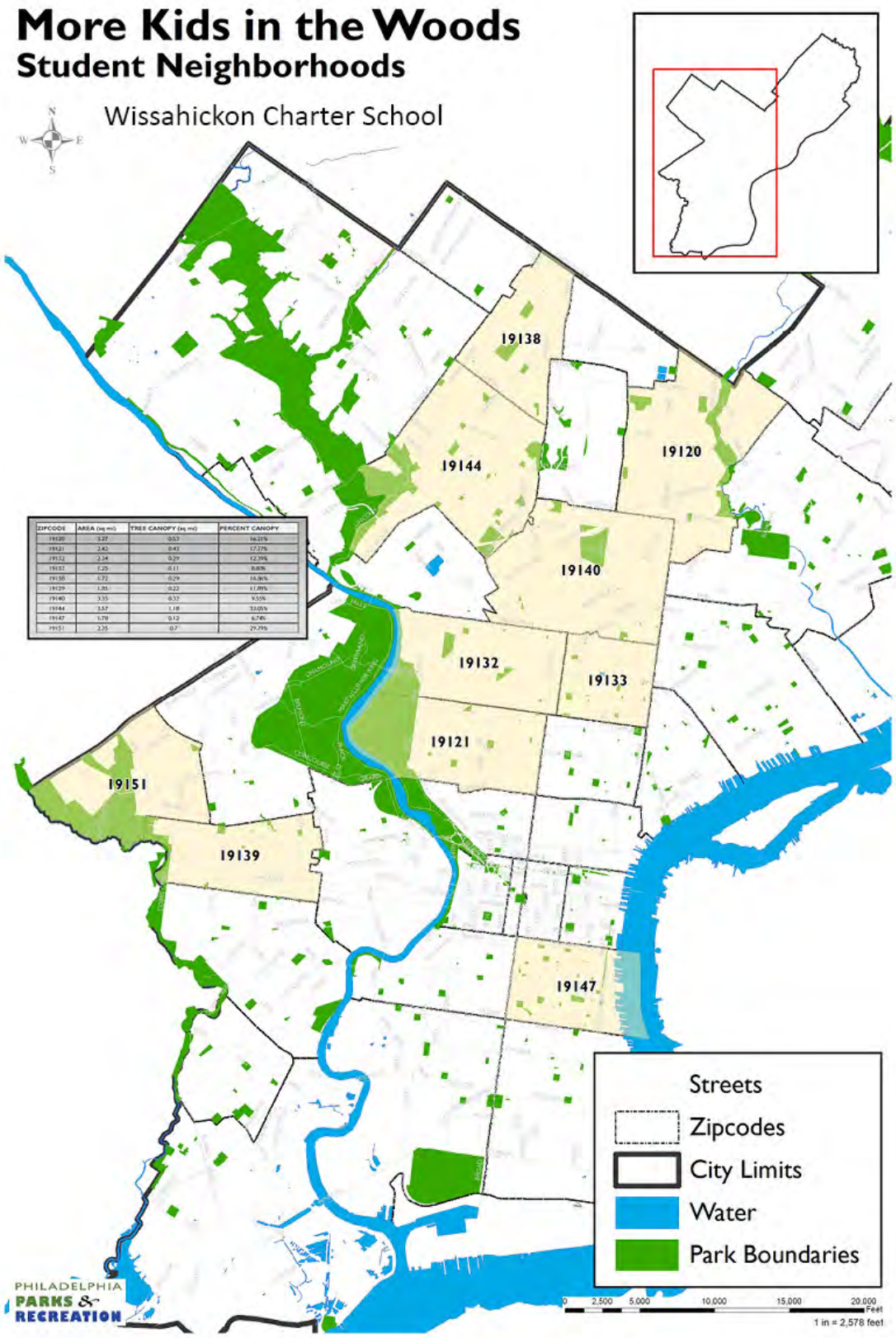
Purples Circles: Pennsylvania School for the Deaf

(Appendix 1)


More Kids in the Woods
School Partnerships
Park Boundaries
Water
Streets
Neighborhood Boundaries
City Boundary
N
W
E
S
PHILADELPHIA
PARKS &
RECREATION

(Appendix 2)

It was difficult to obtain neighborhood information for Wissahickon Charter School classes, but we did obtain the top ten zip codes of where the student population lives. This map was one of the earlier iterations.



TITLE: **THE MORRIS ARBORETUM QUERCUS COLLECTION: UNEARTHING THE MICHAUX QUERCETUM**

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DATE: **May 2013**

ABSTRACT:

The genus *Quercus* (oaks), considered by some the most important hardwood genus, plays a significant role in the Morris Arboretum living collection. A recognized NAPCC joint collection (North American Plant Collections Consortium), the strength of the oak collection lies in its great age and species diversity. The Michaux Quercetum is a distinct collection of oaks within the greater *Quercus* collection, resulting from a large-scale collection of North American oaks in the 1950s. Review of the species diversity, richness, and age structure of the oak collection brings to light a few simple recommendations for the maintenance and enhancement of the nationally recognized collection. The proper maintenance of unique collections projects such as the Michaux Quercetum, combined with oak collection locally and abroad and an increased planting of native oaks, will ensure the high quality of the oak collection at Morris Arboretum in the future.

The Morris Arboretum Quercus Collection: Unearthing the Michaux Quercetum

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INTRODUCTION

Oaks are not the tallest trees, or the largest, or the longest lived, but they have diversified, allowing them to thrive across the globe in vastly divergent habitats. Unlike many trees, the oak genus contains both deciduous and evergreen species. The evergreen oaks evolved for warm climates, while deciduous species evolved for climates with a distinct cold season (Logan, 2006). The oak genus is divided into two sub-genera, the red and the white. The white oaks evolved first and can be differentiated by the smooth, rounded tips of the lobes of their leaves. White oak acorns are fertilized and mature in one season. Red oaks, on the other hand, evolved later in response to a cooling climate. Leaves of red oaks have spiny tips and the acorns take two seasons to mature (Logan, 2006). Accidental crossing or hybridization among oaks is quite common and has caused some controversy within the genus. Some botanists will consider a subject to be a distinct species, while others may label it a hybrid, causing the size of this group to fluctuate according to your (one's) source (Miller, 1985). Considering that, there are about 600 species of oak worldwide and 60 in the United States (Mabberley, 1987).

In many cultures, the oak tree (*Quercus*) has come to symbolize power, protection, strength, stability, and ultimately, life (Nadkarni, 2008). From ancient Norse and Celtic people, to the Greeks, Druids, and Native Americans of California, the oak was sacred, both in its symbolism and function (Nadkarni, 2008). In 2004, the oak was selected as the national tree of the United States in an online election hosted by the National Arbor Day Foundation (Nadkarni, 2008). A press release explained the justification behind this selection:

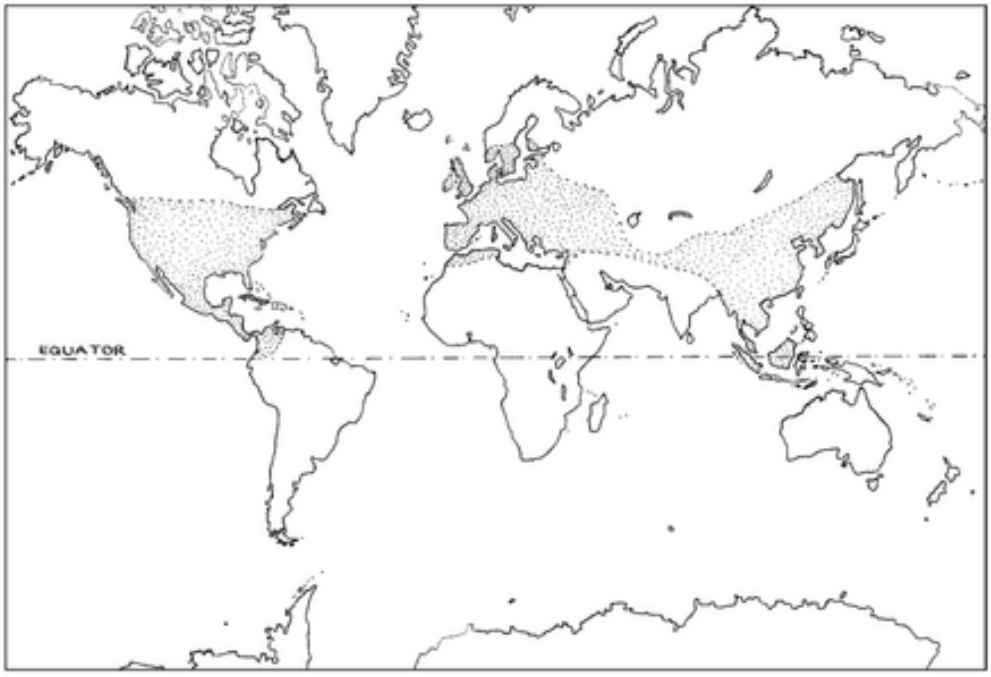
> *"Advocates of the oak praised its diversity, with more than 60 species growing in the United States, making oaks America's most widespread hardwood. Throughout America's history, oaks have been prized for their shade, beauty, and lumber. They have also been part of many important events, from Abraham Lincoln's use of the Salt River Ford Oak as a marker in crossing a river near Homer, Illinois, to Andrew Jackson taking shelter under Louisiana's Sunnybrook Oaks on his way to the Battle of New Orleans. In the annals of military history, "Old Ironsides," the USS Constitution, took its nickname from the strength of its live oak hull, famous for repelling British cannonballs."*

The history of human--oak connection is rich with stories of progress, exploration, prosperity, war, and an evolving world. I will begin my paper by reviewing some of the roles oaks have played in human society over time in order to position the *Quercus* collection of the Morris Arboretum within its greater context, providing a crucial backdrop with which to interpret, maintain, and plan for the future of, our collection.

THE HUMAN--OAK CONNECTION

William Bryant Logan's book, "Oak: The Frame of Civilization" is a comprehensive and fascinating read for those interested in the natural history and folklore surrounding oaks. He began his investigation with a rather keen observation, namely, that the world oak distribution is "coterminous with the locations of the settled civilizations of Asia, Europe, and North America" (see Figure 1). He does not postulate that oaks trees were a condition for these civilizations, instead, he simply draws attention to the fact that "where there are or have been cities and cultures that shaped the modern world, there are or have been oaks" (Logan, 2006).

Figure 1. Worldwide Distribution of Oaks (Nora Logan)



The poet Hesoid praised the generosity of the oak, for he claimed it "yielded three fruits-acorns, honey, and galls-- while other trees yielded but one." (Logan, 2006). Archeological evidence of grinding tools before wild wheat was cut for human consumption supports the stories by Hesiod, Ovid, Lucretius, and Pliny, among others, which spoke to the role acorns played in diets of the Arcadians, an ancient, pastoral people who lived on the edge of the Mediterranean. The evidence of oaks as a major food source can also be found in human language, such as the old Tunisian word for oak that means "the meal-bearing tree." Many Native American tribes such as the Ojibway, Menomenee, Iroquois, and Apache were also balanocultures, derived from the Greek *balanos* ("acorn"), meaning acorn-eating cultures. Acorns are still enjoyed today in traditional Korean, Chinese, and Turkish meals (Logan, 2006). In his book, Logan experiments with cooking and eating acorn products (flour and jelly) acquired from a local Korean market. Although not particularly flavorful, he found these creations to be exceptionally filling, a significant characteristic that has become almost completely irrelevant in the world of overabundance in which many of us currently reside. Inspired by Logan's culinary adventuring, I

also purchased acorn flour from a nearby Korean market, and with the help of fellow intern, Jamie Berlin, crafted delicious acorn molasses cookies to share at my project presentation (for recipe see Appendix 1).

When Bloomfield Farm Horticulturist Louise Clarke returned from her work exchange at Windsor Great Park last summer, she spoke to me of the ancient oaks she had encountered during her time in England. They were magnificent, decaying beasts, gnarled and wounded, that made our America oaks look like mere children by comparison. Prior to the publishing of Logan's book in 2006, the famous Dotard Oaks of Windsor had been threatened by the expansion of highway A332, but the local community had fought to protect the trees and succeeded in blocking the road from being widened. Champion oaks are celebrated and protected throughout the United States as well. One example of these locally, and sometimes nationally, famous oaks is the Wye Oak of Maryland. Purchased by the state in 1939, the surrounding 30 acres was converted into a state park in its honor. The Wye Oak inspired Fred W. Besley, the first Maryland State Forester, to found the Big Tree Champion Program in 1925; as a result, the American Forestry Association named the Wye Oak one of the first National Champion Trees in 1940. When the Wye Oak tragically failed in a storm back in 2002, it was more than 460 years old, and the largest white oak tree in the United States, measuring 96 feet tall with a trunk diameter at breast height of 31 feet 10 inches (Logan, 2006).

The wood of oaks was once valued for many tasks necessary for human life, including "roadways, frames, doors, palisades, hinges, barrels, coffins, boats, tanning, and ink." From the first boardwalks allowing travel through wetlands to the unparalleled dominance of oak-built ships and the tanning of leather, oak products have played a key role in human society. In the age of wooden ships, oak was the first choice for shipbuilding as it was strong, comparatively light, watertight, bendable, and most importantly, workable. Used in both Viking longships and renowned American Naval ships such as the USS *Constitution* ("Old Ironsides"), it is without a doubt that oaks are responsible for some of the most significant ships ever built (Logan, 2006). Besides ships, oaks have been used to create many laborious masterpieces, such as the revolutionary 660-ton oak roof of Westminster Hall constructed for Richard II between A.D.1393 and 1397 (Logan, 2006). Although somewhat less grand, the chemical properties of oak bark were essential to the tanning leather, which prevented the animal skin from rotting and made it supple and quite waterproof (Logan, 2006).

Another practical application of oaks unique chemistry was the gallo-tannic acid derived from many oak galls that was used in the production of one of the first "true inks." True inks differed from earlier inks as they sunk quickly into the paper and oxidized, binding to the very fabric of the page, while the latter bound to the surface of the page and were easily smudged or erased. Although present in many oak galls, the highest concentrations of gall-tannic acids can be found in the galls of small scrub oak abundant in Turkey, and so named *Quercus tinctoria*, the ink oak. The oak gall ink was clear, produced a sharper line than other inks, and was virtually permanent. For these reasons it became the popular choice for government documents,

architectural drawings, artist's renderings, and any other precise and long-lasting documents. Some famous examples include, the U.S. Constitution, the Declaration of Independence, Thomas Jefferson's elevations of Monticello and the University of Virginia, as well as the notebooks of Leonardo da Vinci, the music of Bach, and the drawings of Rembrandt and van Gogh. Unfortunately, this ink was not actually as permanent as it seemed at the time, and recently many historic texts written in oak gall ink have been lost as the ink steadily degrades the cellulose on which it was written (Logan, 2006). Recently, visual artist Susan Deakin from the UK produced a work called "Contemplation Drawing, 431 years." The piece illustrates the cross section of a 431 year old English oak (*Quercus robur*), each annual growth ring painstakingly drawn in oak-gall ink (see Fig. 2).

Figure 2. Susan Deakin, "Contemplation Drawing, 431 Years"

Oaks produce many useful products desired by humans, and so to ensure sustainable harvesting, forest management techniques were instated, in some places resulting in the first "forest law." One management technique I found particularly compelling was the *dehesas* of southwestern Spain, which combined agriculture, the production of firewood and charcoal, acorn harvesting, cork production, and the rearing of livestock efficiently on one tract of land. A *dehesa* looks like a park, yet produces more per acre than any system of modern agriculture. However, the *dehesa* only produces small quantities of many things. The principal trees are evergreen oaks, *Querucs ilex* and *Q. suber*. The trees are surrounded by grasses and planted with grape, chickpeas, broad beans, and wheat in the sunny openings. The acorn mast fed pigs, sheep grazed the grasses, selective pruning provided firewood, and opportunistic agriculture provided fruits, vegetables, and legumes (Logan, 2006). To me, *dehesas*, typically communally owned and operated, perfectly encapsulate the guiding principle of permaculture, a popular reemerging trend today that aims to create a highly efficient and productive system through stacking functions, mixed-use space, and closed-loop nutrient cycling.

The pre-Christian religion of Druidism worshipped the spirits of trees. The oak was the sacred tree of this intellectual and powerful Celtic class, and they venerated mistletoe, which

grew on its branches. Each tribe possessed a sacred meeting place enclosed by trees. This is where their local deity was believed to reside, and the destruction of these sacred groves was viewed with the same horror that the bombing of a mosque or burning of a church would incite within us today. After the Roman conquests, Druids were suppressed and practice carried on in secret in caves and forests. By the seventh century, many Druidic practices had almost completely died out, although the Christian church had managed to absorb many of its practices. Eleven centuries later, Druidism saw a huge revival in England, with such notable Britons as William Blake and Winston Churchill initiated into the Drudic orders. Modern day Druids are especially concerned with issues of the environment, including the distribution of information on global climate change (Nadkarni, 2008).

The peak of oak-derived products has since past, and once the most important hardwood species, oak lumber is now reserved for truck floors and middle-market cabinets (Logan, 2006). Virtually every part of the oak tree, from the wood to the bark to the acorns and galls, was at one point a valuable commodity to humans. Today a small contingent still take advantage of the many uses of the oak, but the vast majority of the population see them merely as a street tree, or a symbol of fall, or just another tree in the forest. The history of the human--oak connection is incredibly complex, engaging, and inspiring. However, the importance of oaks is more than just their practical uses, their landscape and ecological value is remarkable in and of itself and further cause to protect, plant, and maintain this incredible group.

HISTORY OF MICHAUX QUERCETUM

Francois Andre Michaux (1770-1855) was a noted French botanist and early plant explorer commissioned by the French government to inventory trees of eastern North America (1802). His exploration resulted in the publication of "*Histoire des arbes forestiers de l' Amerique septentrionale*" in 1810. This visually stunning piece was illustrated by the French artist Pierre Joseph Redoute and detailed the possible commercial and artistic uses of North American trees. His travels and publications established Michaux as an early student of American forest trees, with a special focus on oaks (APS, 2013). Elected to the American Philosophical Society late in life, upon Michaux's death in 1855 he bequeathed a fund to them "to be used for furthering the progress of forestry and agriculture in the United States." The Michaux Fund of the American Philosophical Society acted in part to fund the Michaux Quercetum project, and hence it bears his name. The word quercetum is Latin derived, meaning "an oak grove" or "an oak forest."

Figure 3. Oak illustrations by Pierre Joseph Redouté from *Histoire des arbres forestiers de l'Amérique septentrionale*

The majority of the Michaux Quercetum is located on a total of 5 acres of the Bloomfield Farm property of the Morris Arboretum of the University of Pennsylvania. This project originated as a collaboration between the Morris Arboretum and the Northeastern Forest Experiment Station of the Forest Service, U S. Department of Agriculture, financed in part by the Michaux Fund of the American Philosophical Society. The purpose of the project was to establish a "comprehensive living collection of all climatically amenable species and varieties of oaks" (Schramm, 1954). The Quercetum was designed for "maximum practicable of usefulness in theoretical and applied research" within the fields of breeding, taxonomy, progeny tests, and tests of exotic species (Schramm, 1954). The establishment of such an authenticated collection of oak species, both native and exotic, would provide germplasm for breeding and extensive hybridization within what was thought of as "the most important hardwood genus" (Schramm, 1954). Oaks are known as a highly complex and taxonomically confounded genus due to their intricate evolution processes and ease and frequency of hybridization. At the time the Quercetum was founded, approximately 80 species of oaks, in addition to 20 varieties and several hundred presumed natural hybrids, had been described in the United States (Schramm, 1954). It was believed that given a facility such as the Michaux Quercetum, studies could be undertaken to delineate and establish the validity of our native species. Such studies would provide crucial information on the existing variation within oak species, as well as the existence and distribution of oak races. Finally, this project would serve as preliminary hardiness tests for exotic species from all temperate oak-inhabited parts of the northern hemisphere (Schramm, 1954).

For each species selected for inclusion in the project, 100 seeds (acorn) were collected from individual native trees with a known geographic location in wild natural stands. The collection of seed was accompanied by a herbarium specimen prepared from the same tree from which the acorns came. In the case of species with wide distributions occupying more than one climate zone, separate seed and herbarium collections were obtained from two individual trees of a species when possible. For the purposes of this project, natural hybrids were not included as they were identified as having "less scientific usefulness while at the same time enlarging the

undertaking to unmanageable proportions." Acorns were planted immediately upon arrival in rodent-proof seed beds underlain by flyscreen wire cloth to prevent the development of a tap root. Seedlings remained in the seed bed for one year, during which time they began collecting hardiness data. Next, individuals were moved to the expansive Quercetum nursery where they were grown for up to four years and studied for variability and any evidence of hybridity. Seed lots yielding progenies true to the parental type and not significantly variable were transplanted into the permanent Quercetum after 5 years. Individuals in the Quercetum were planted on 20-foot centers and grouped by species in order to facilitate collaborative studies. Additionally, to account for possible soil differences throughout the site each seed lot was replicated three times in different areas of the planting. Lastly, open spaces allotted to each species were left vacant to allow for future out plantings (Fogg, 1956). If the nursery produced excess seedlings, every effort was made to place these seedlings into collections serving objectives similar to those stated above (Schramm, 1954). Accordingly, excess plant material from the nursery was distributed and duplicate plantings were established at Longwood Gardens, Holden Arboretum, University of Washington Arboretum, Ohio Agricultural Research & Development Center, College of William and Mary, and the University of Wisconsin, among others, which act to provide valuable comparative data (Willaman et al. 1973 and personal communication, Tony Aiello).

This project became active in the spring of 1953, but collection efforts were confined to temperate North America for the first year of operations. Agencies, individual botanists, and foresters had all been invited to collaborate in the collection of acorns and the preparation of the supporting herbarium specimens. At the end of the first collection season (1953), a total of 29 botanists and personnel of the U.S. Forest Service had sent in 150 separate seed collections representing 37 species from 23 states. Each collaborator was given instruction on collection procedures in addition to a small assemblage of materials to assist in the collection and mailing process (for "Suggestions for Collaborators" see Appendix 2) (Schramm, 1954).

In 1955, Hui-Lin Li wrote a "Progress Report on the Michaux Quercetum." At that time the number of collaborators had grown to 45 botanists and 41 persons belonging to 14 different Forest Service stations. In total, the 1954-55 season had added 240 acorn collections consisting of 40 species and 9 varieties from America and 4 foreign species (Fogg, 1955 and Li, 1955). Overall, the Michaux Quercetum consisted of collections from 33 states in addition to Quebec, Canada. Of the 26,000 total seeds planted, 14,500 of those had germinated, resulting in a grand total of 11,000 young trees and seedlings planted out in the nursery (Li, 1955).

The project leaders behind the Michaux Quercetum had planned on continuing this project in future years and to extend the area of collecting to include portions of Europe, the Near East and the Orient (Fogg, 1955). Unfortunately, as you may have guessed, these ambitious goals for the project were never achieved, and acorn collection for the project ended after the 1954-1955 season.

As planned, the Michaux Quercetum project resulted in many research publications in the decades immediately following its establishment. Research topics ranged from the performance of western and southern oaks (Santamour, 1960), to the juvenile variation in white and red oaks (Schreiner et al. 1961a, 1961b), and oak provenance research (Santamour et al. 1980), among others. The last comprehensive progress report was authored by Willaman, Hsiao and Li in 1972 and summarized the research and development of the Michaux up until that time. At that point, the collection consisted of 239 trees representing 20 species (of the original 40) adapted to the Philadelphia climate. The report included growth rates, hardiness factors, and climate and soil influences, which allow this document to act not only as a progress report but also supply proper documentation to support further scientific study (Willaman et al. 1973). Active research on the Michaux Quercetum appears to have ceased after 1980, although this planting remains a valuable resource for addressing many questions pertaining to oak breeding, taxonomy, progeny tests, and evaluation of exotic species.

CURRENT STATE OF QUERCETUM

When I arrived as an intern at the Arboretum in the summer of 2012, I was immediately intrigued by the cathedral-like grove of even-age oaks and their foreign sounding name, "the Quercetum." Once a hub of scientific research, the Michaux Quercetum now occupies a lonely corner of the Bloomfield Farm and its story is unknown to most employees. A problematic access road through the planting had resulted in soil compaction and the failing health of several of the specimens.

Currently there are 109 accessioned trees in the Quercetum, 80 of which hail from the original Michaux Quercetum project. Overall, the Quercetum includes 30 taxa: 23 species, 1 subspecies, 4 varieties, and 2 hybrids. Heavily thinned since its originally planting in 1956 (Paul Myer, personal communication), the original 20-foot centers have increased significantly, invoking in the visitor a sense of spacious majesty. Unlike the companion Michaux planting at Longwood Gardens, our Quercetum is actively managed and maintained by mowing, pruning, removals, and other measures as necessary. Conversely, the Michaux planting at Longwood Gardens is no longer an active part of the living collection (not accessioned) and has been allowed to return to a natural stand with a relatively dense understory of hollies and beeches (Personal observation and personal communication, Andrew Lyman). Holden Arboretum and Washington Park Arboretum were not visited as part of this project, but the Michaux plantings at these institutions are being maintained and inquiries have been made to Morris' plant recorder, Elinor Goff, about the history of these trees so that they may further understanding and care for this unique collection.

The early stages of my project focused on identifying candidates for removal and the rerouting of the access road to minimize compaction of the root zone of healthy specimens. Since I began working on my project last August, three declining trees have been removed from the Quercetum: *Quercus macrocarpa* (53-390*C), *Q. velutina* (53-441*C), and *Q. rubra* (53-526*C). These removals allowed the rerouting of the access road to a less problematic location as well as opened the canopy up, allowing for the possibility of new plantings. Accordingly, last October Bloomfield Farm Horticulturist Louise Clarke and I were able to plant two young oaks in this area, *Quercus falcata* × *velutina* (2006-116*B) and *Quercus robur* ssp. *pedunculiflora* (2006-148*A). Louise Clarke and I have also identified an oak to plant out into the Quercetum as part of the spring 2013 planting (*Quercus robur* ssp. *pedunculiflora* (2006-148*B)). The specimen was planted in April of 2013. I am very grateful to the work of assistant arborist, Andrew Hawkes, and arborist intern, Fabrice Rochelemagne, who air spaded the root zone of several Quercetum oaks and erected guideposts to keep vehicles off the newly aerated areas. Additionally, Andrew air spaded drainage ditches to move rainwater off the new road, which will reduce pooling water and keep the road in better condition.

THE QUERCUS COLLECTION

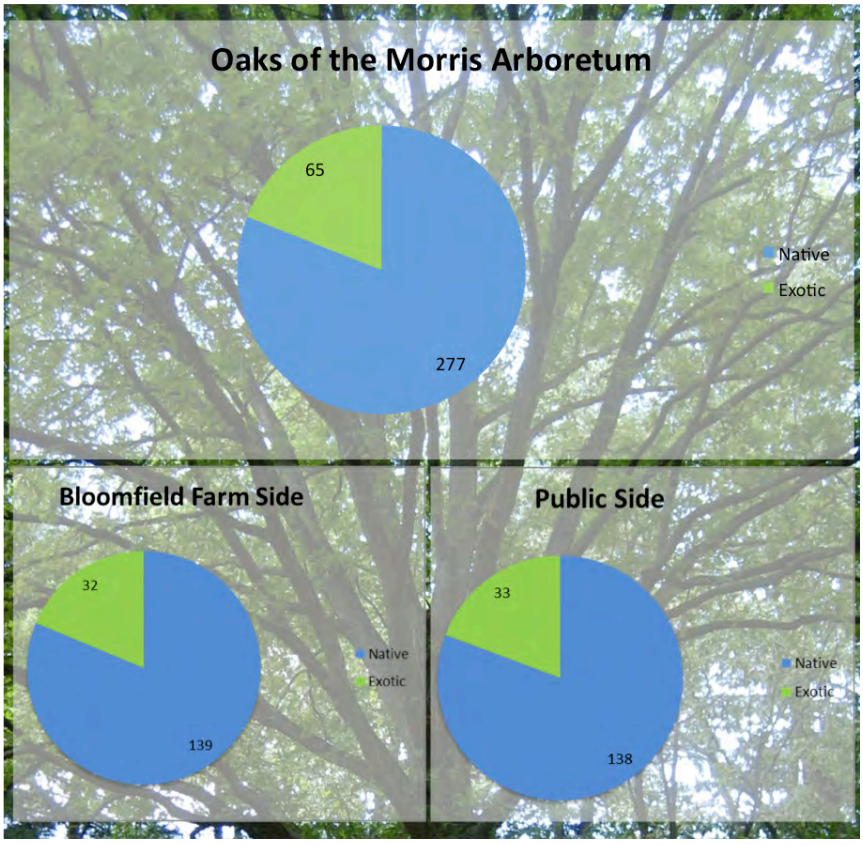
The *Quercus* collection is one of the Morris Arboretum's three NAPCC (North American Plant Collections Consortium) recognized collections, the other two being *Abies* (firs) and *Acers* (maples). The Morris' NAPCC oak collection is a joint collection with other botanical institutions throughout North America (for list of partner institutions see Appendix 3). The NAPCC was developed by the American Public Gardens Association (APGA) in cooperation with the USDA Agriculture Research Service and the U.S. National Arboretum. The program was designed to recognize superior collections and curation within the field in order to develop a national network of botanic gardens and arboreta promoting high standards of plant collections management and conservation of plant biodiversity (APGA, 2013). Acceptance into the NAPCC program is added recognition of the Morris Arboretum's long-term commitment to preserving plant collections and to achieving the highest standards of excellence in collections management.

The *Quercus* collection of the Morris Arboretum, consisting of 54 taxa, is notable for its diversity of age and species. Several specimens from before and during John and Lydia Morris' time predate the Arboretum itself, such as the Bender oak (*Quercus* × *benderi*) at the top of the hill, white oaks (*Q. alba*) on the Magnolia Slope, and the large oaks in English Park (*Q.* × *bebbiana* and *Q. prinus*). The collection also includes trees added as part of the previously discussed Michaux Quercetum Project. These specimens are located on the slope above the rose garden and as part of a large grove at Bloomfield Farm. More recent additions to the collection originate from plant collecting trips to Korea, China, and other locations, such as the Oriental white oak and Daimyo oak (*Q. aliena* and *Q. dentata*), are planted throughout. Collections

recognized by the NAPCC must meet certain criteria, such as a "long-term institutional commitment to collect, document, grow, and maintain living plants of a particular taxon and conserve this germplasm," "back-up replicates and long-term germplasm storage desirable to ensure preservation," as well as "regular collections updates and periodic on-site evaluations" (for complete list of criteria see Appendix 4).

Curator, Tony Aiello, and I were interested in the break down of the *Quercus* collection in terms of age, nativity, and their geographic location within the collection. We postulated that native oaks would typically be older specimens, and that they would be concentrated on the Bloomfield farm side of the Arboretum. As of April of 2013, of the 342 total *Quercus* plants, 277 are species native to Pennsylvania and 65 are exotic. We then separated the specimens by location within the Arboretum to test our theory that the public side would have a greater percent of exotics and the Bloomfield Farm side would have a greater percent of natives. However, we found the two sides of the Arboretum to have almost equal ratios of native to exotic oak species (138:33 and 139:32 respectively, see Fig. 5).

Figure 4. Oaks of Morris Arboretum (number of plants).



After considering the diversity of the collection at a relatively large scale, native vs. exotic, I determined species diversity and richness for both the Bloomfield Farm and public sides of the Arboretum (see Fig. 5 and 6). As you can see, both charts illustrate a similar pattern,

whereby each side of the Arboretum has many plants for a few select oaks (such as *Quercus alba, Q. rubra,* and *Q. velutina* on the Bloomfield Farm side) and few or a single accession for the majority of oak species.

Figure 5. Oaks of Morris Arboretum: Bloomfield Farm (number of plants per taxon).

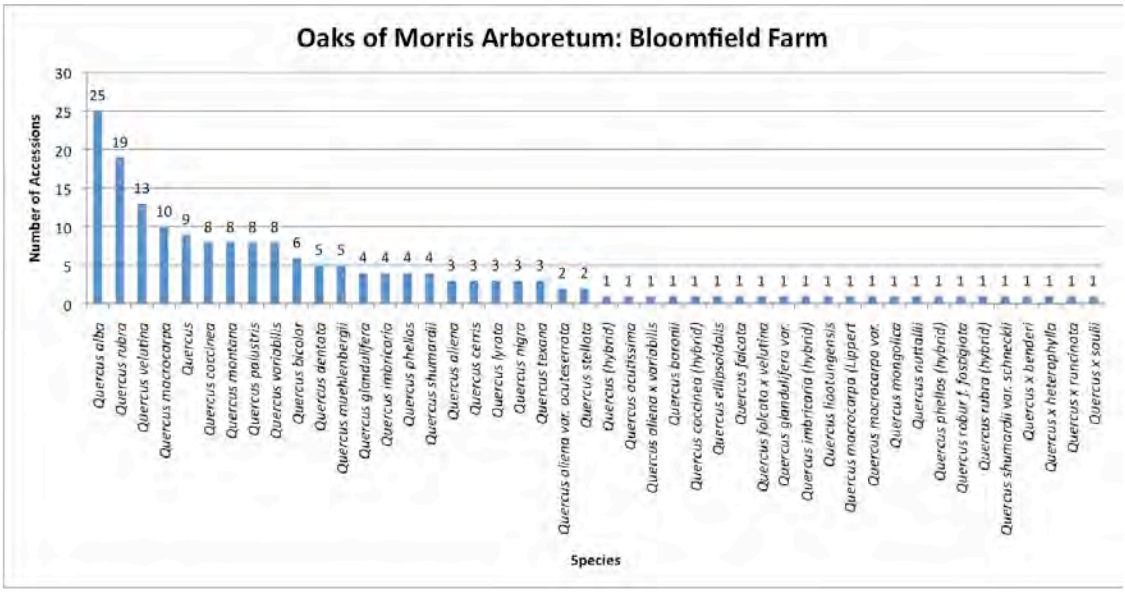
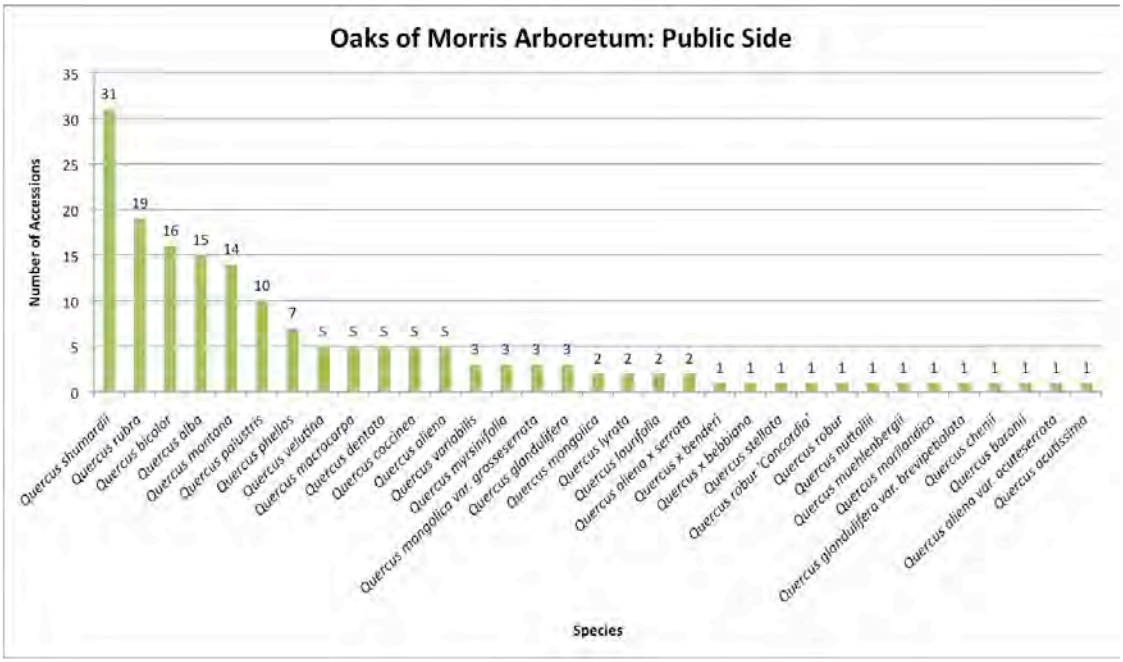


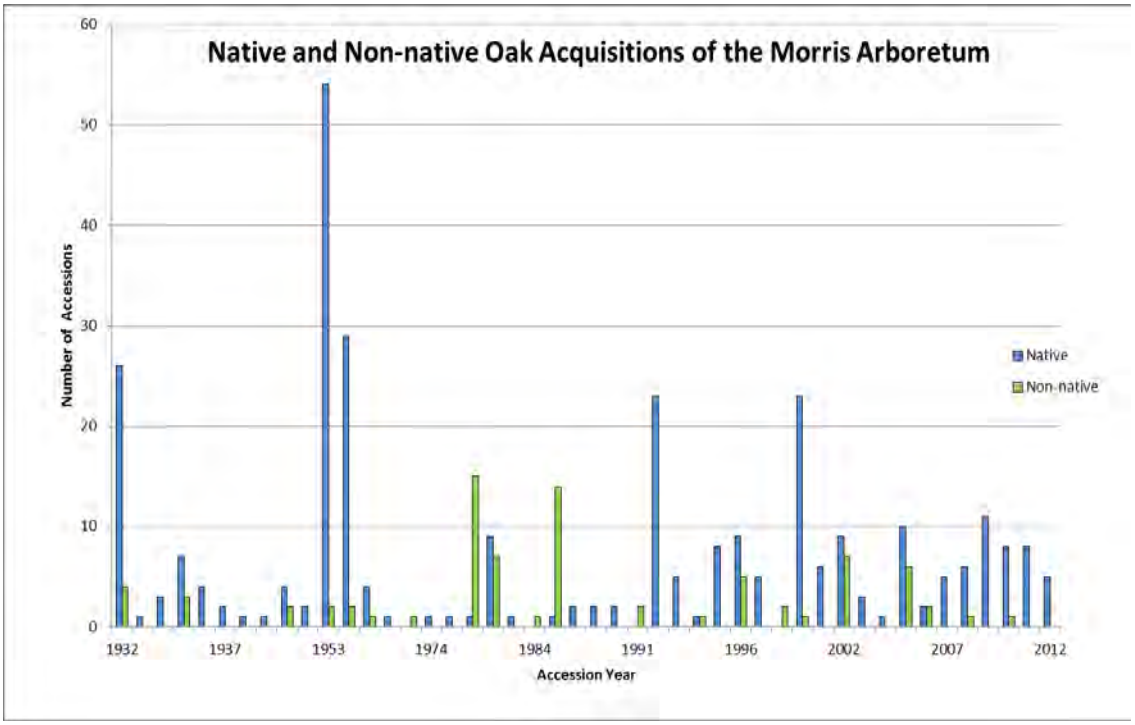
Figure 6. Oaks of Morris Arboretum: Public Side (number of plants per taxon).



Next, I looked at the acquisition of oaks by the Arboretum over time. For the purposes of looking at the age structure of the collection, I used accession date as a proxy for age. In Figure 4 below you can track the development of the Morris Arboretum *Quercus* Collection from 1932

until present (2013). The bar graph is accented by a few distinct times of rapid and massive oak acquisition. The first point of interest is the establishment of the Arboretum in 1932. As all existing plants on the property were accessioned in that year, and accession year of 1932 tells us very little about the age of the specimen, however it provides us with a snapshot of the *Querucs* collection at that time. As you can tell from the chart, native oak species far outnumbered exotic oaks at the time the Arboretum was founded, partially due to what species were readily available at the time. The next noteworthy peak is the extreme influx of native oaks in the early to mid 1950s with the creation of Michaux Quercetum project. In the 1970s and 1980s there are a few years of large exotic additions to the oak collection as a result of plant collecting trips to Korea, Taiwan, and other parts of Asia. Every year since the influx of native oaks into the collection has far outweighed that of exotic species.

Figure 7. Native and Non-native Oak Acquisitions of the Morris Arboretum (number of accessions per year)



In addition to collecting trips abroad, two recent collection projects of native oak species have added to the *Quercus* collection at the Morris Arboretum. This past year, Tony Aiello and collaborator Michael Dosmann, of the Arnold Arboretum, traveled to the northern range limit of the southern live oak (*Quercus virginiana*) in Virginia in an effort to collect seed from individuals potentially cold hardy enough to survive Boston and Philadelphia winters. Another more local project collected seed of the native willow oak (*Quercus phellos*) in Bucks County, PA, some of which has been planted within the arboretum and some distributed to the wider community (Personal communication, Tony Aiello). By balancing local, native oak collection with exotic oak collection in Asia and other parts of the world, the Morris collection maintains diversity, a robust source of germplasm, and supports knowledge of regional and global flora.

CONCLUSIONS AND RECOMMENDATIONS

The oak collection at Morris is very well developed with high species diversity and a robust age structure. In order to maintain and improve upon the high quality of the current collection, I have a few recommendations for additions and management. Our representation of the oaks of Pennsylvania is quite strong. Of our native species, we are only missing two, *Quercus ilicifolia* and *Q. prinoides*. If possible, completing our collection of native oaks will strengthen our commitment to the local flora of Pennsylvania as well as improving Morris as a teaching facility for local flora.

I mentioned the two collections case studies of native oaks (*Quercus virginiana* and *Q. phellos*) to highlight a highly beneficial practice to our oak collection that should be continued in years to come. Although slightly less exciting and foreign than collecting trips to Korea or China, collection and propagation of North American natives equally strengthens our *Querucs* collection, bringing increased depth to our educational capacity, diversity of germplasm, and even increases the resiliency of our collection in the face of changing climate.

Lastly, although oak diversity at the Morris is relatively high (54 taxa), some species are only represented by one individual. If that one individual were to be lost for any reason, we have completely lost that species from our collection. I would encourage the Arboretum to increase the representation of these species, where possible, in order to make the collection more resilient and improve upon its educational capacity. A complete list of underrepresented species can be found in Appendix 5.

In conclusion, the *Quercus* collection of the Morris Arboretum has an extremely rich and interesting history that has resulted in the incredible collection we all enjoy today. The preservation of unique collection efforts such the Michaux Quercetum provides an interesting window into the history of the Arboretum, enhances the diversity of our collection, provides a valuable teaching tool, and provides a high quality system for future oak research. I hope that by synthesizing the history of the project into a single, accessible document I will raise awareness about this interesting endeavor and the importance of our oak collection overall. I am very pleased that Morris' Living Collections pays tribute to the deep connections between humans and oaks, while also promoting plant conservation and education, and I hope to see the *Quercus* collection properly grown and tended for many years to come.

ACKNOWLEDGEMENTS

I would like to thank Pat and Chuck Crafts of Hay Honey Farm and Morris Arboretum staff members Paul Meyer, Tony Aiello, Louise Clarke, Bob Wells, Bob Gutowski, Elinor Goff, Andrew Hawkes, Frabrice Rochelemagne, and Andrew Lyman for their support and assistance.

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APPENDICES

Appendix 1. Acorn Molasses Cookie Recipe (Rose Barlow)

¾ brown sugar
¾ cup butter
1 lg. egg
¾ cup molasses
1 ¼ cups acorn flour
1 ½ cups flour
1 tsp baking soda
½ tsp salt
1 ½ tsp ginger
1 tsp cinnamon
1 tsp nutmeg
½ tsp allspice

1. Cream the brown sugar and butter together.
2. Add eggs and molasses, and mix thoroughly.
3. In a separate bowl, mix together flour, acorn flour, baking soda, salt and spice.
4. Add dry ingredients to wet and mix thoroughly. Batter should be soft rather than stiff, but not runny.
5. Drop by rounded spoonfuls on to a cookie sheet. Flatten them with your palm and sprinkle with sugar crystals.
6. Bake at 325 for 8-10 minutes. Be sure not to over-bake, as the bottoms burn easily.

Appendix 2. Collecting Procedure for Michaux Quercetum (Schramm et al. 1954)

A. Collecting Procedure

For each species or variety, collect:

I. *From a single wild tree in a natural woodland.*

a. 100-125 acorns as soon as ripe, and 6-12 cupules;
b. A typical leafy branch (if possible with a few cupules attached) for use as an herbarium specimen.

It is basically important that all acorns, cupules and the specimen *unquestionably come from the same individual tree*. Usually this can best be assured if the items are collected from a tree with low hanging branches on the edge of a woodland.

Avoid trees which might possibly have been planted, also any which are suspected of being hybrid.

Reject acorns which show any sign of weevil infestation; acorns dropping early are often very heavily weeviled.

II. *From another tree in the same locality* make if possible a second collection exactly as outlined in I. above, keeping it as an *entirely distinct and separately numbered collection from the first one.*

B. Materials Furnished to Collaborators and Mailing Procedure

For each collection (individual tree), the following are furnished:

1 polyethylene bag with sealer
1 self-addressed cloth bag
1 numbered stainless steel tree tag with copper nail
1 numbered collector's field label
2 numbered string paper tags

Appendix 3. NAPCC Multi-Institutional *Quercus* Collection

Chicago Botanic Garden
Cornell Plantations
Davis Arboretum at Auburn Univ.

Denver Botanic Gardens
Holden Arboretum
Landis Arboretum
Missouri Botanical Garden
Morris Arboretum
The Morton Arboretum
Mount Auburn Cemetery
New York Botanical Garden

Rancho Santa Ana Botanic Garden
Scott Arboretum
Starhill Forest Arboretum
Univ. of CA Botanical Garden
UC Davis Arboretum
Univ. of WA Botanic Gardens

Appendix 4. Required Criteria for NAPCC Collections

Question:
What are the criteria required of NAPCC participants?

Answer:

- Long-term institutional commitment to collect, document, grow, and maintain living plants of a particular taxon and conserve this germplasm
- Governing body's support, including provision for adequate and sustained resources for collection
- Collections policy
- Designated curator for the collection
- Collections maintained according to professional standards
- Reasonable access to collections for research, evaluation, and introduction
- Back-up replicates and long-term germplasm storage desirable to ensure preservation
- Regular collections updates and periodic on-site evaluations

Appendix 5. List of underrepresented species in *Quercus* Collection (for the purposes of this list "underrepresented" is defined as three or less accessions within the collection)

Quercus acerifolia	1
Quercus acutissima	2
Quercus aliena × *serrata*	2
Quercus aliena × *variabilis*	1
Quercus boyntonii	2
Quercus cerris	3
Quercus chenii	1
Quercus ellipsoidalis	1
Quercus falcata	3
Quercus falcata × *velutina*	2
Quercus glandulifera var.	2

brevipetiolata	
Quercus ilex	1
Quercus ilicifolia	1
Quercus laurifolia	2
Quercus liaotungensis	2
Quercus mongolica	3
Quercus mongolica var. grosseserrata	3
Quercus myrsinifolia	3
Quercus nigra	3
Quercus nuttallii	2
Quercus pagoda	1
Quercus petraea ssp. iberica	1
Quercus prinoides	2
Quercus robur	1
Quercus robur 'Concordia'	1
Quercus robur f. fastigiata	1
Quercus robur ssp. pedunculiflora	1
Quercus shumardii var. schneckii	1
Quercus texana	3
Quercus vaseyana	1
Quercus ×bebbiana	1
Quercus × benderi	1
Quercus × benderi	1
Quercus × heterophylla	1
Quercus × runcinata	1
Quercus × saulii	1

TITLE: **FERNERY WEBSITE UPDATE: A GUIDE TO THE FERNS IN THE FERNERY**

AUTHOR: **Stephen Pyne, The Martha J. Wallace Endowed Plant Propagation Intern**

DATE: **March 2013**

ABSTRACT:

In order to further the educational mission of the Morris Arboretum of the University of Pennsylvania, as well as expand the visibility of its website, and create a valuable internet resource, this project creates an online guide to the ferns in the Dorrance H. Hamilton Fernery. The content for this guide is stored in a MySQL database. Online users can access this content in the Fernery section of the Morris Arboretum's website. PHP scripts format the fern information so that users can access it with any modern web browser. These scripts also provide tools for Fernery staff and volunteers to update and maintain the information in the database.

Fernery Website Update: A Guide to the Ferns in the Fernery

TABLE OF CONTENTS

INTRODUCTION AND GOALS

The Dorrance H. Hamilton Fernery contains a huge diversity of ferns. There are close to one hundred species of ferns representing over 40 genera. To further the Arboretum's mission to educate its visitors, it is ideal to provide botanical information about each fern. Physically labeling every fern in the Fernery would mar the beauty of the landscape. Instead this can be achieved optimally by means of an online guide to the ferns of the Fernery.

Creating this guide in the form of an online database has been a primary goal of this project. The database was designed to contain every fern in the Fernery, allowing users access to basic botanical information about the ferns, as well as to provide several photos to help identify each fern. This online database will be accessible through the Fernery website so that it can be used not only as a resource for people trying to identify ferns in the Fernery, but also as a general internet resource for temperate and tropical ferns.

Because the Fernery is not a static installation, the content of the database cannot be static. As plants grow, move, die, and change, so too must the content of the database. For that reason, the database has a clear and easy-to-use administrative interface so that the Fernery staff and volunteers can maintain and update its contents. Because the administrative interface is online, it also needs to be secure so that only authorized personnel can access it.

Building on the work of previous interns has been another goal of this project. Joshua Darfler, an intern from 2011-12, created a wonderful webpage containing good general information about the Fernery. With this webpage already in place, I have been able to spend my time exclusively on developing the database. Additionally, Bianca Mary Jessica Knoll, plant propagation intern in 2002-3, worked on identifying and photographing the ferns in the Fernery as well as in the rest of the garden. The Excel spreadsheet inventory that she produced has provided much of the material for the fern database and her beautiful photos were used liberally as the identifying pictures. Using the work of previous interns not only creates a better final product, but also honors their contributions and brings their work to a wider audience.

DATABASE SETUP AND PROGRAMMING

I chose to use a MySQL database with PHP because of its ubiquity in the internet world and my familiarity with both. MySQL (My Structured Query Language) is an open source, relational database. It is currently owned by Oracle, but its code is freely available. It is used widely over the internet including some very well-known websites (Wikipedia, Facebook, and Craigslist). It is often paired with PHP (PHP: Hypertext Preprocessor) which is an open source scripting language that is imbedded in web pages. It works by running the PHP script imbedded in a file before the web server sends the user that file. That PHP script tells the server to get information from the database and how to include it in the webpage. It is formatted so that user's web browser can read it just like a normal web page, but it now includes content from a database, such as a list of all the ferns in the Fernery, or specific information and photos about a particular fern.

DATABASE STRUCTURE

The core of this project was the creation of the database. Nineteen fields were defined, and they are as follows:

ID : Unique numeric identification key for the database

SciName : Scientific Name of the fern

SynName : Any synonymous scientific names for the fern

ComName : Common Name(s) for the fern

Origin : Where the fern is native

Location : Where this fern is currently planted at Morris Arboretum

Acquired : Date fern was acquired – purchased, collected, sown, etc

Source : Where fern was acquired

Removed : Date fern died or was removed from the collection

CultInfo : Cultural information: what this fern needs to survive

MiscInfo : Miscellaneous information about the fern

GHNumber : Greenhouse accession number

Pres2003 : Was this fern present in B. Knoll's survey of the Fernery in 2003? This field is not displayed to the public.

Notes : This field is for in house record keeping. It is not displayed to the public.

PlantPhoto : Name of the picture file that shows the whole fern

FrondPhoto : Name of the picture file that shows the fern's frond

SoriPhoto : Name of the picture file that shows the fern's sori pattern

CrozierPhoto : Name of the picture file that shows the ferns crozier

OtherPhoto: Name of the picture that show other aspects of the fern (fertile fronds, rhizomes, bulbuls, etc)

WEB PAGE FILES

Once the database was created, the next task was to create the web pages that would allow access to its content. These pages are generated by the following PHP scripts:

admin.php – This is the script that generates the pages used to administer the database. When using the administration section, the Fernery staff person or volunteer will come first to a page that requests a password. This ensures that the rest of the administrative pages remain private and secure. (The administrative section includes a page where this password can be changed.) Once the correct password has been given, the user can add or remove ferns, as well as edit the fern information. It also allows the uploading of photographs in the jpeg format. When a picture is uploaded to the website, its location is noted in the database so that it can be associated with that particular fern. Also a smaller version of the photo, a thumbnail, is created so that a quick-to-load picture gallery can be created for the fern. An illustration of the fern editing administration page can be found in this paper's appendix.

fern.php – This is the script that generates the pages viewed by the public. It will generate an introductory page to the database, as well as the individual fern pages. The introductory page describes the purpose of the database as a guide to the ferns in the Fernery. It also has a list of all the ferns by name, with a link to their individual pages. There is a simple map of the Fernery as well. If the user clicks on a section of this map, a list appears of ferns that are in that section of the Fernery. The ferns in that list will be linked to their individual pages. The individual fern pages will be divided with pictures on the left and text on the right. The text will give basic information about the fern: Scientific Name, Common Name, Country of Origin, etc. The picture part will have a large thumbnail, as well as several smaller thumbnails. By clicking on a thumbnail a large version of that picture will fill the browser window. From there you can either view the other pictures, or return to the main page. On the main page there is also a pull down menu that allows the user to select a different fern and view that fern's page. In the appendix there are two examples of these individual fern pages.

In designing the gallery viewer portion of the fern page, several options were explored. The goal was to have a quick loading initial page. This meant no big images. It was important for the user to be able to view a full resolution version of the image so that identifying characteristics could be more easily seen. The final requirement was that the gallery viewer would work on as many platforms as possible: computers, tablets, and smart phones. The solution that seemed to meet all these requirements was YoxView, a freely available, Jquery based, javascript plug-in. So while the PHP scripts created and organized the image files, YoxView ultimately displays the full sized images.

fern_template.html – This is a simple HTML file that has header and footer information that make all the pages look like they are part of the Morris Arboretum Website. The other PHP scripts look for the comment field:
<!-- This is where the fern database will insert content -->
and inserts the script generated content into that section. This formatting information should make it easier for Arboretum web masters to modify the look of the script generated pages without having to go into the scripts themselves.

header.php – This script is used by both admin.php and ferns.php. It contains the basic information for accessing the database as well as the header and footer information gleaned from the fern_template.html file.

WEBSITE MODIFICATION

The Arboretum's website required little modification to allow users access to the database. The only section that was modified was Joshua Darfler's Fernery webpage. A side box, formatted in the same manner as the self-guided Fernery tour box, creates a portal to the database's introductory page. See appendix for an illustration of the modified website.

Although it did not fall within the scope of this project, I highly recommend that the Morris Arboretum website be reconfigured so that the Fernery section is more visible and easier to find. Currently it is not possible to go directly to the Fernery section from the homepage. One must first pull down the 'Gardens & Exhibits' menu and click on 'Arboretum Features', from there 'Buildings' must be selected, and then finally the link to the Fernery section is available. As a unique and crowd-drawing feature, I would place it in the same category as the Garden Railway and Out on a Limb.

CONCLUSION

Much like the work that came before this project, this online guide to the ferns of the Fernery is a work in progress. An online guide exists. It can and hopefully will be used by our guests to further their understanding of the ferns in our Fernery. The tools are in place for the continued maintenance and updating of this resource. This project also creates a new foundation for others to build upon. I fully expect that our website will change and the work of this project will mutate and change along with the website. At some point in time this database might be used to create self guided tours. QR codes on labels could access the information contained in the database. Wifi technology could be installed in the Fernery so that visitors could access the database while they are there. Whether it be smart phones, qr codes, or google glasses, as technology and the expectations of our visitors change, so too must we.

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Appendices

Updated web page

Always Growing

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Official arboretum of the Commonwealth of Pennsylvania

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The Gardens & Exhibits

- General Information
- Plant Collection
- Arboretum Features
- Horticulture Center
- History
- Mission and Vision
- Tree Adventure
- Garden Railway

Garden Buildings

The Dorrance H. Hamilton Fernery

Select a Building

- Dorrance H. Hamilton Fernery
- Gates Hall
- Greenhouse Complex
- Horticulture Center
- Log Cabin
- Mercury Temple and Grotto
- Pumphouse
- Springfield Mills
- Springhouse
- Widener Visitor Center

Ferns of the Fernery
A Guide to Our Fern Collection

Click to **view** the ferns of the Dorrance H. Hamilton Fernery"

The Dorrance H. Hamilton Fernery is the only remaining freestanding Victorian fernery in North America. Originally built in 1899 under the supervision of John Morris, the fernery stands today as a historical time piece, documenting the British obsession with ferns and glasshouses during the Victorian era. The building was constructed using locally mined stone and utilized cutting edge technology in glass cutting, steam heating, and architectural elements.

In the century following the original construction, the fernery slowly fell into disrepair, with several small renovation projects to protect it from destruction. Finally in 1994 the fernery was fully restored to its original grandeur with a gracious donation from board member Dorrance H. Hamilton and other contributors who responded to a major matching grant from the National Endowment for the Humanities. This $1.2 million renovation included restoring the roof to the original curvature, replacing and updating the heating and electrical systems, installing an advanced climate control system, and restoring the waterfall, ponds and stone walls. The blue flagstone plaza was also installed during this project to welcome visitors, and provide a shaded relaxing place to stop and enjoy the arboretum.

Self-guided Tour of the
Dorrance H. Hamilton Fernery

Click to **download** a Self-guided Tour of the Dorrance H. Hamilton Fernery"

Nestled in a curve of land below the rose garden, the fernery has become an iconic part of the Morris Arboretum. Its glittering rooftop welcoming visitors into a peaceful space filled with ferns, trickling waterfalls and reflecting pools. A wonderful place to explore in all seasons.

Interactive Timeline

1887 | 1898 | 1915 | 1917 | 1932 | 1956 | 1987 | 1994

Sample Fern Pages

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Blechnum brasiliense

Common Name(s): Brazilian tree fern
Location: right rear
Country of Origin: Brazil
Misc. Information: This small tree fern has beautiful red croziers and new fronds. As the fronds age they turn a bright green. It is native to Brazil and other parts of South America.

Blechnum brasiliense | View a Different Fern

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Quercifilix zeylanica

Common Name(s): oak leaf fern
Location: Front
Date acquired: 1996
Source: Logee
Country of Origin: China, Taiwan, Malaysia, Sri Lanka, Mauritius
Misc. Information: steps to tunnel

Quercifilix zeylanica | View a Different Fern

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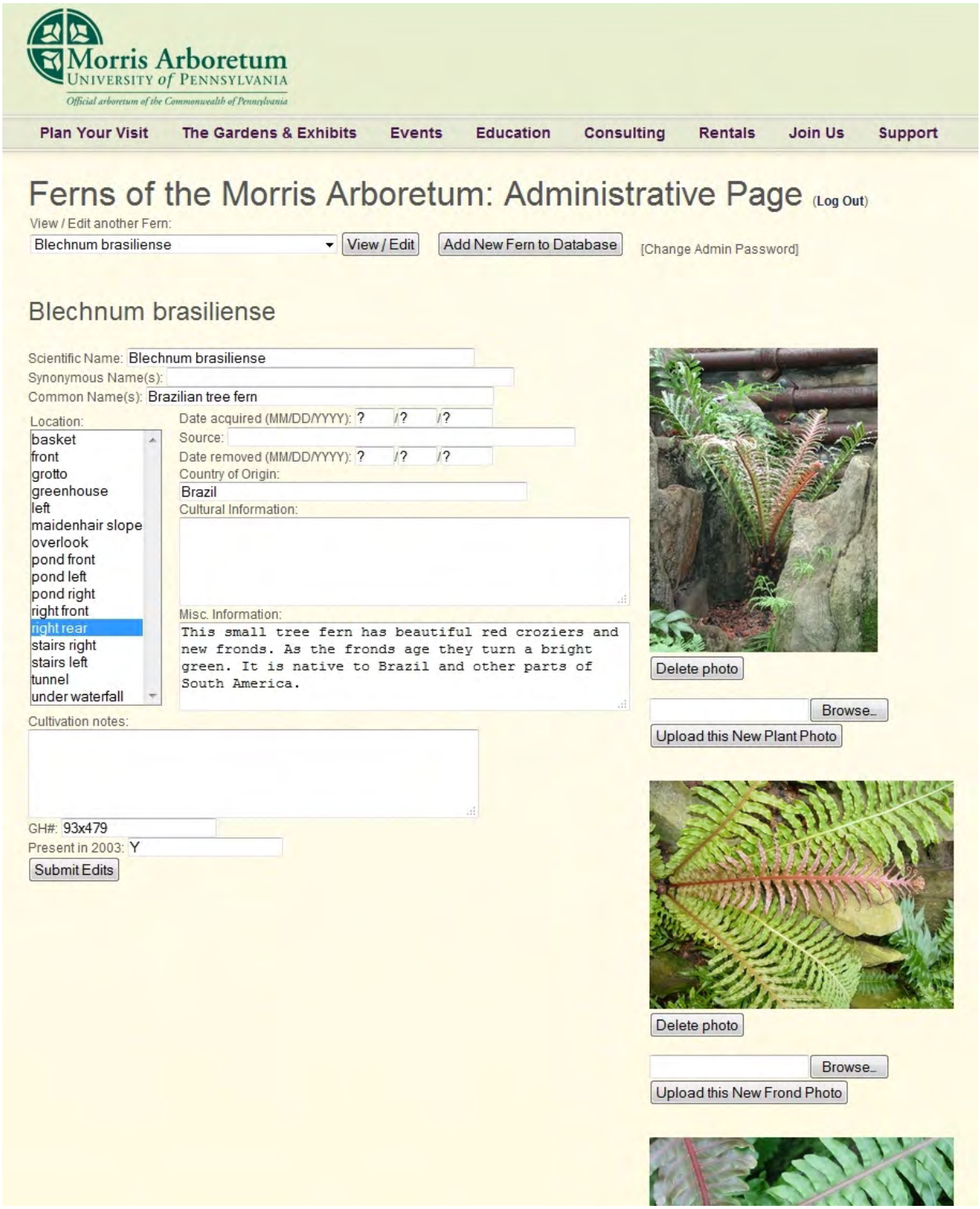
Administration Page



TITLE: **READING THE COOKIE: A STUDY OF TREE ANATOMY, PHYSIOLOGY, AND WOOD DECAY**

AUTHOR: **Fabrice Rochelemagne**
The Walter W. Root Endowed Arborist Intern

DATE: **March 2013**

ABSTRACT:

This project seeks to educate and inspire wonder in the hearts and minds of the public for the biological practices of 'our tall brothers,' through the display and interpretation of prepared anatomical samples extracted from removed trees at the Arboretum. Included samples were selected for visual appeal, clearness of anatomical features, and illustrative character. Each sample was removed and shaped by a chainsaw. The internal surfaces were brought into focus with a planer and/or belt sander, and finished, if applicable, with shellac. Each sample was selected and prepared to help illustrate concepts about tree anatomy and physiology.

As a whole, these concepts serve as a fundamental basis of knowledge that enables one to 'read the cookie' as it were. By understanding these concepts we can begin to see the internal history of trees; we can know their struggles and understand the forces that shaped them.

As a product, this project is a tool intended for use in various educational scenarios. The samples can be displayed on their own, or used supplementally, for illustrative purposes, for any of our educational or outreach programs. Most likely, only the anatomy samples will be useful with small children, but they are designed for use with children or adults, the depth of discussion can be determined by the instructor accordingly. Several pieces were selected for their small size, enabling them to be handled and passed around easily in the classroom.

To facilitate explanation, the concepts were described in educational PowerPoint slides complete with photos, illustrations, and notes from various sources. Both the slides and the samples could be used together or separately as fits the educational scenario best.

Reading the Cookie: A Study of Tree Anatomy, Physiology and Wood Decay

TABLE OF CONTENTS

INTRODUCTION

The Morris Arboretum features wonderful educational infrastructure and programming. The *Out on a Limb* exhibit provides a great macro view of forest ecology and canopy habitat structures, not to mention a totally unique perspective, and our classes and volunteer guides provide students and visitors with a solid base of knowledge about trees: how they grow and evolve, their place in the ecosystem as organisms and as habitat, and what we can do for them to be good stewards. I believe an appropriate addition to our arsenal of instructional materials dealing with trees is something that addresses their internal anatomy and physiology. These subjects are often difficult to illustrate in a way that grabs the viewer's attention, and much of the terminology can be cumbersome. However, as the arborist intern, I am exposed to the internal anatomy of trees frequently, and so I decided to take advantage of this by extracting woody samples to serve an educational purpose.

The idea for this project came from a desire to show people what the internal history of trees looks like, and how to read it. I became interested in the subject myself during pruning and removal operations. There can be so much learned about a tree when one dismantles it.

Accompanying the collection of samples, I've prepared a PowerPoint presentation. The samples and PowerPoint could each be used on their own, or together, as needed by the instructor. The basic intent is that the samples give the students something real that they can hold, look at, and
hopefully wonder about, while the PowerPoint can help define as well as expand what they find in the samples. However, I further hope that whoever uses these materials is able to find ways to modify and adapt these samples and slides to serve them better as a learning tool; for I am not a professional educator and I am sure there are elements that I have missed.

RESULTS

A "cookie" is a cross section of a woody stem whose diameter is larger than its length. By examining a cookie, many things about the woody plant's life can be determined: years when it was young and grew fast, years when there was a drought, or a fire, years when it was wounded, by a sapsucker or a buck for instance, or years when it grew slower... Much can be learned, but one needs to know how to look. This project serves as a tool that can help build a fundamental base of knowledge that students can use to read a woody plant's cookie, or other anatomical samples. I believe this educational tool is useful because it provides another way for visitors to learn about trees, a critical part of our natural world. In addition to cookies, I prepared several other types of samples using radial and tangential cross-sections. These cuts help display other features like branch attachment or decay columns.

ANATOMY SAMPLES

The prepared samples were selected for visual appeal, clearness of anatomical features, and illustrative character. Some are labeled, but others are intentionally left blank, this way, the instructor can use them in some type of activity in which the students are required to do their own identification of features. They've been cut to a size that should be convenient to store and handle, but still gives enough illustrative character to be useful. When features in the wood needed to be brought out better, the piece was sanded for better definition.

I have experimented with using shellac to finish and help preserve the pieces, but wonder about other finishes like linseed oil or polyurethane (shellac was selected to make the colors "pop," but perhaps linseed oil, which shows off the grain better, or polyurethane, which finishes the wood true to color, could work better). Some pieces or surfaces of pieces were left unfinished in order to show the student the contrast between prepared and unprepared surfaces.

Sanding can be tedious, but I found that the work on smaller samples was carried out easier by turning the belt sander upside down, balancing it against the ground, and bracing it between my knees. This way, I could run the sample against the sander with more control. This is an inherently dangerous activity however, so make sure one is aware of the risks and wears proper PPE (gloves, eye and ear protection, sturdy pants).

CONCEPTS

Whether presented on their own, or integrated into a larger lecture, I have arranged the concepts in a specific order in the PowerPoint presentation. The reasoning for this is that each subsequent concept is meant to further extrapolate a former concept, allowing the student to learn more from the things they already know. For example, most people know something about a tree's annual rings; it is probably the first thing they imagine when they think of a tree's insides. Thus it is the first concept.

Some concepts are presented in a twofold fashion, such as sapwood and heartwood, because their definitions can be understood as difference, i.e. both sapwood and heartwood are made of the same tissue, xylem, but sapwood is still conductive, while heartwood is not. These concepts of sapwood and heartwood, which themselves are commonly known, function to organize the former concept, annual rings, into two distinct zones. Xylem and phloem, as concepts, divide the concept of annual rings a second time, and introduce two botanical terms. Shigo's theory of C.O.D.I.T. is famous among anyone that works with trees in a professional capacity, but for the average person it is most likely unknown. However, it is connected to the first concept in that the second wall is an annual ring, and the fourth wall is the additional annual ring that is formed when the tree lays down new wood the following spring after wounding.

Some concepts depicted in the slides, like the cellular structure of wood, or the strategies of the different types of wood decay, are most likely too complicated for younger audiences. But these concepts could be explained simply through the use of the anatomical samples, using the activities listed below.

ACTIVITIES

Because each sample piece can illustrate multiple concepts, it is probably best to review the concepts if they are not already familiar, before going into activities. Like most things, activities are limited only by imagination.

I am assuming a small group of six to fifteen individuals, ages ranging from four or five years and upwards, with twenty to thirty minutes of activity time. Below, I list a few ideas. The configuration of each assumes a small to medium sized group with a time slot of twenty to thirty minutes, but, through modification this time frame can be reduced or enlarged.

1. Pass out samples of wood rots. Larger pieces can be broken so that everybody has a crumb.

Start with brown rots. Have the students write down (if they can write, otherwise they can do it verbally) descriptive terms as they observe and dissect the samples in their hands. Move on to white rots (soft rots won't be included because texturally they are too similar to brown rots) and repeat procedure. Discuss contrasts and then introduce lignin and cellulose, explaining how, because the fungus breaks down components selectively, the rots result in different textures. Finish with a discussion of what might happen when these rots grow in standing trees.

2. Pass out various samples showing scars and stubs. Talk about how a tree might be mechanically injured (do not forget lightning strikes). Ask the students to describe what they think is happening in the samples. If they are on the right track, give them a cookie (woody or otherwise). Facilitate the explanation by pointing out key features if the student seems stuck.

   Talk about the differences between scars and stubs, in terms of what patterns of decay these injuries may induce in the tree. Finish with a talk about how a hollow tree forms. Does it start from a stub or a scar? How does it form (get bigger)? What stops it? You could go on to talk about the animals that live in hollows and why they are critical for the ecosystem.

3. Pass out gnarly samples and ask students to guess what caused these injuries. If the wound was older, ask them to find out how old. Get them to calculate how old they were when the wound occurred (if they can). Did any of the wounds occur before a student was born? Next have them look at growth increments. See if they can tell when a tree was growing at its fastest, slowest, are there any rings missing sides? Talk about why a tree grows fast, whether that's good or bad; why a tree grows slowly or not at all, etc. Ask them whether they would rather be

   a tree that grows slow or fast, giving examples (slow like an oak/ginkgo/beech or fast like a tulip poplar/willow/tree of heaven). Give them a breakdown of the pros and cons of growth rates.

4. Pass out samples that depict compression wood and ask the students what they think caused the rings to form like that. Facilitate with questions that help focus their attention if necessary. Once they have discovered that it is because a stem was leaning as it grew, ask them to show which way the stem was leaning using the sample. Talk about how compression wood forms, and if they know about lignin and cellulose, include that in the explanation. Ask them to identify the year in the stem's life that it began to lean. Have

them brainstorm what causes woody stems to lean. Finish with a distinction between tension wood and compression wood.

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TITLE: **FROM PAST TO FUTURE, REVITALIZATION OF THE POLLINATION/MEADOW GARDEN AND A SITE ASSESSMENT FOR THE BAXTER MEMORIAL**

AUTHOR: **Heather Schmidt**

The Charles S. Holman Endowed Rose and Flower Garden Intern

DATE: **April 2013**

ABSTRACT:

The primary objective of the project is the completion of detailed analysis work of the area currently known as the Baxter Memorial and the Pollination Garden. Located at a highly visual intersection of the Pennock Garden, Rose Garden, and Garden Railway areas, the site provides an opportunity for a gathering and educational space. Analysis work covered topics of context, historical analysis, existing conditions, current vegetation, circulation, soils, focal points, views-vistas, topography, and hydrology. This is all compiled into an opportunities and constraints (potential and problem areas) analysis, which is a discussion of the analysis results.

Following the analysis phase is a research phase. This phase examined case studies of projects with similar themes, learning from their successes and failures. Potential site materials such as the path surfaces and furnishings were also studied. Regionally appropriate native plants were studied to understand their benefits and associated relationships to wildlife including: birds, bees, flies, butterflies, and biological control insects.

The final objective is to create a design proposal for the site including a planting design and species list. This phase will also look at how the design will be implemented. The garden will educate visitors of all ages about the evolutionary relationships between plants, pollinators, and wildlife. This educational garden will include signage and potentially a sculpture (created by Greg Leavitt) to create an entry focal point. The sculpture will memorialize Samuel Newman Baxter and his horticultural contributions to the Philadelphia region. This is to be a multi-use space that connects and relates to the Arboretum through aesthetic, mission, and forward vision.

From Past to Future, Revitalization of the Pollination/Meadow Garden and Site Assessment for the Baxter Memorial

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INTRODUCTION

To understand how a designed space can be implemented, one must first understand a site's progression. This is accomplished by first studying its context, ecology, and the cultural history of the space. The early stages of this project began with a detailed analysis of the site currently known as the Baxter Memorial and an area known as the Pollination Garden. Further analysis of soils, vegetation, topography, hydrology, views, focal areas, and circulation were completed. These analyses are described in full detail and can be observed through plans and, when applicable, charts are included.

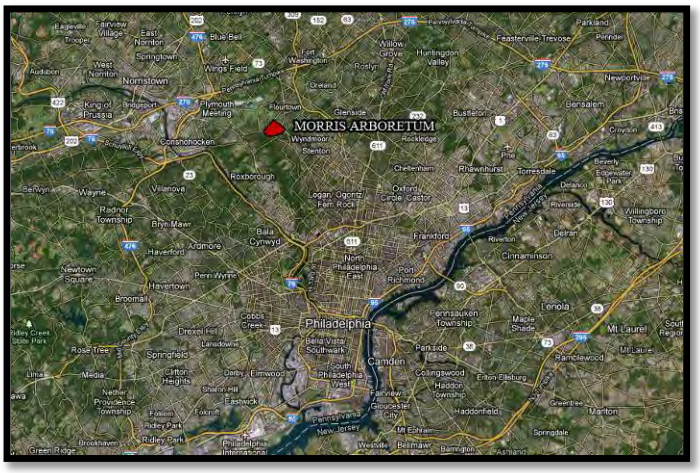
The analysis and revitalization of design work for this area utilized former intern projects. Claire Collie's project in 2009-2010 established the concept of a pollination garden, which reworked a 20-year-old meadow garden. Shea Zwerver, in 2010-2011 completed a study-survey of sacred sites valued most by visitors to the Arboretum. Zwerver's research revealed visitors are seeking native plants, sculpture, and planned views. Lukas Spetlik completed a study of the most important views of the Arboretum in 2005-06. These results were beneficial for the early stages of analysis work and for identifying the significant view of the valley.

As a final compilation of the analysis phase, a constraints and attributes analysis was completed. These results are beneficial for the design proposal, planting design, and plant list to create a space that meets the mission and design aesthetic of the Morris Arboretum. This is to be a highly educational garden for visitors of all ages to instruct about the evolutionary relationship between plants, insects, and wildlife. This is to be a multi-use space that connects and relates to the Arboretum through aesthetics, mission, and forward vision.

ANALYSIS PHASE

Site Context and Regional Ecology:

To fully understand the context of the site within the Morris Arboretum one needs to first review the regional setting. The Arboretum is located in southeastern Pennsylvania along the far northwest border of Philadelphia County, which borders Springfield Township in Montgomery County.



Source: Google Maps

The Arboretum is located physiographically in the Northern Appalachian Piedmont Province, which runs through Southeastern PA. Regionally this area of Pennsylvania receives approximately 35-50 inches of precipitation a year falling predominantly in the spring and early summer months. Climate is classified as humid, with cold winters and hot summers having 170 to 210 days without killing frost. All of this information is necessary to select native plants appropriate for the site.

The proposed garden site is located at the crossroads of the Rose Garden, Pennock Garden, and Garden Railway, making this a vital connection space between the gardens and other areas of the Arboretum. This juncture is one of the most visited sites in the Arboretum, receiving high traffic and visual attention. The site includes the current Pollination Garden installed in 2010 and the Baxter Memorial, installed in 1948-49. These two separate spaces are located close to each other, but do not connect in terms of circulation or relate through design aesthetic and theme.

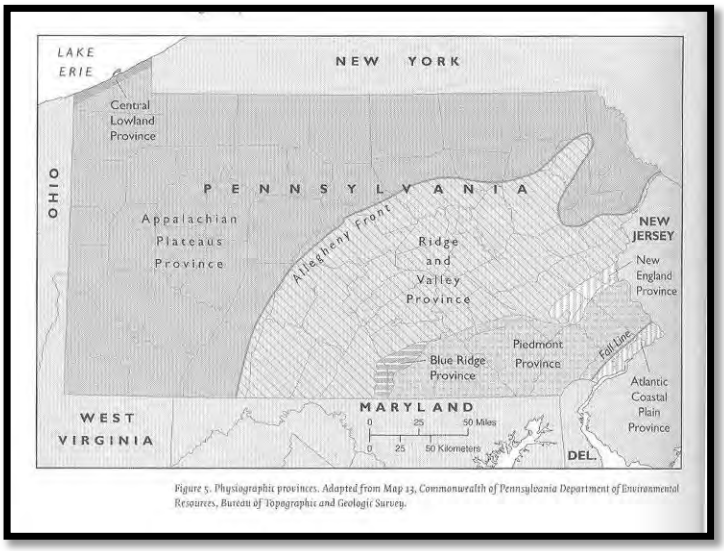


Figure 5. Physiographic provinces. Adapted from Map 13, Commonwealth of Pennsylvania Department of Environmental Resources, Bureau of Topographic and Geologic Survey.

Source: "The Flora of Pennsylvania" Dr. Ann Rhoads and Dr. Tim Block

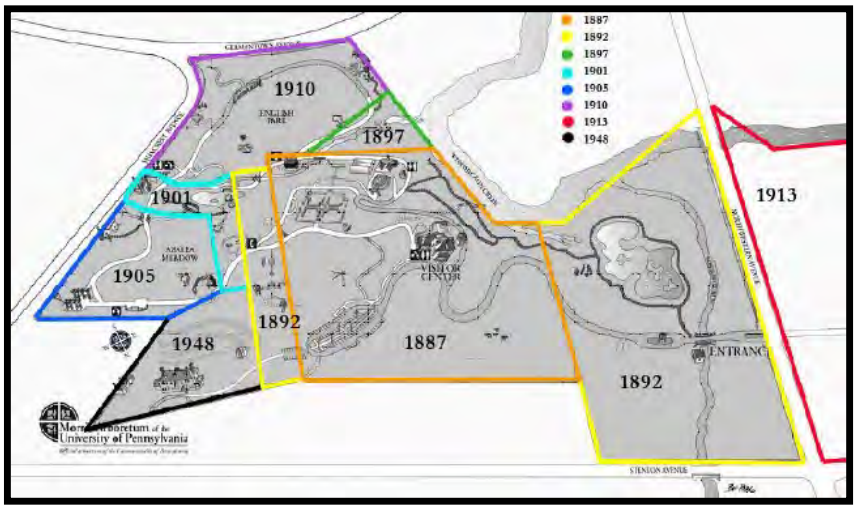
Source: Google Maps

Source: Google Maps

Source: Google Maps

Historical Analysis/Context:

Compton, the Morris estate, was the summer home of siblings John and Lydia Morris. Purchased by John Morris in 1887, the property was an empty pallet for the Morrises to create their landscape. It was donated to the University of Pennsylvania in 1932 at which time it was renamed Morris Arboretum. This is also when the first accession of plant collections occurred.



"Historic Sequence of Land Acquisition at the Morris Arboretum"
Source: www.morrisarboretum.org

The current property is 166 acres, but property expansion evolved in seven phases during the Morrises' time. The University of Pennsylvania added a final property addition in 1948, Gates Hall. The Arboretum property was added to the National Register of Historic Sites in 1978.

The site chronology can be summarized starting with the Morris plantings of the Flower Walk. This area most likely lasted until 1948 when the Baxter Memorial and plantings were installed. . The current Pollination Garden first began as a Meadow Garden in early 1990's by Rosarian Judy McKeon. Rosarian Mike Tuszynski transformed it into the meadow garden in 2002. The space was reduced in the mid to late 2000's due to setbacks with weeds. In 2009-10, a pollination garden was installed to update the garden and interpretive signage was added.

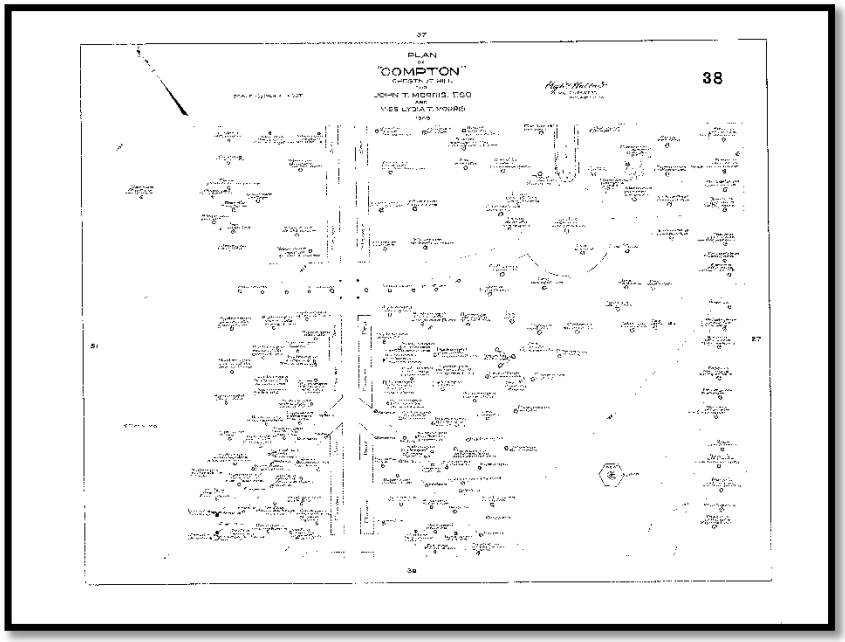
Flower Walk:

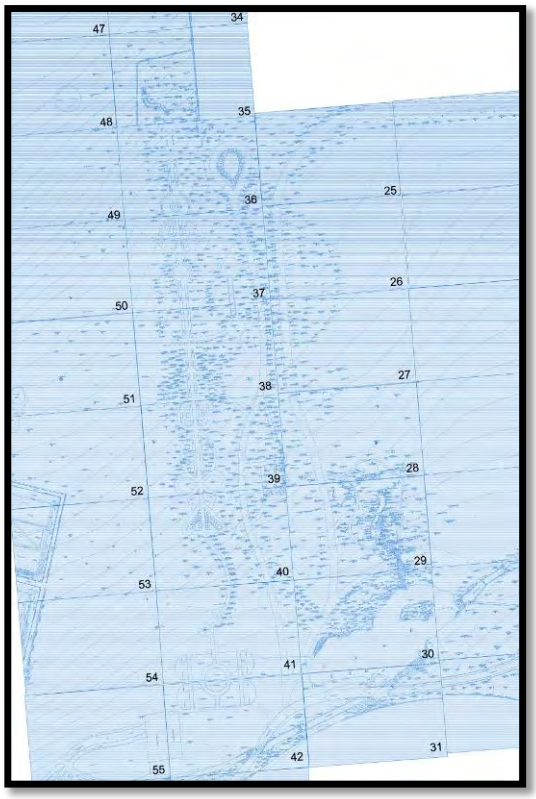
Originally the Morrises developed a long axial English-style garden called the Flower Walk starting from the remaining Orange Balustrade through today's Pennock Garden and ending at a former rose garden near the pond and creek. This axial garden featured a variety of highly ornamental plantings.

Main Flower Walk or Snowball Arch-Viburnums (Pennock Garden), May 24, 1937

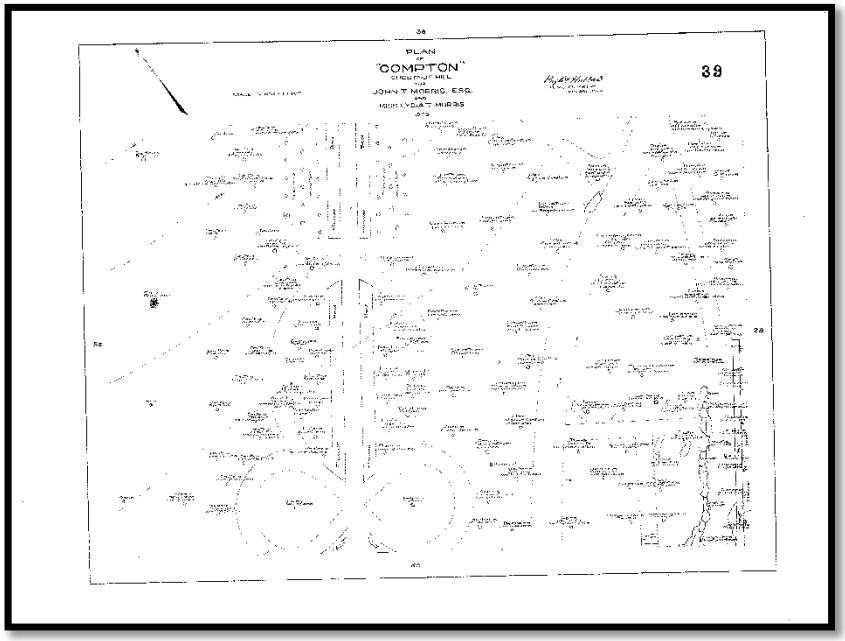
Flower walk (Sundial Garden), 1930's

When studying the 1909 Flower Walk planting plans, the focused site area reveals plantings of: *Paeonia moutan*, *Hydrangea*, *Viburnum*, *Hypericum*, *Caragana*, *Deutzia,* and *Hamamelis*. Other areas along the walk included displays of: *Diervilla*, *Spiraea*, *Yucca*, *Syrianga*, *Pieris*, *Erica*, *Hibiscus*, *Pyrus*, *Berberis*, and *Forsythia*.





1909 Planting Plan: #38

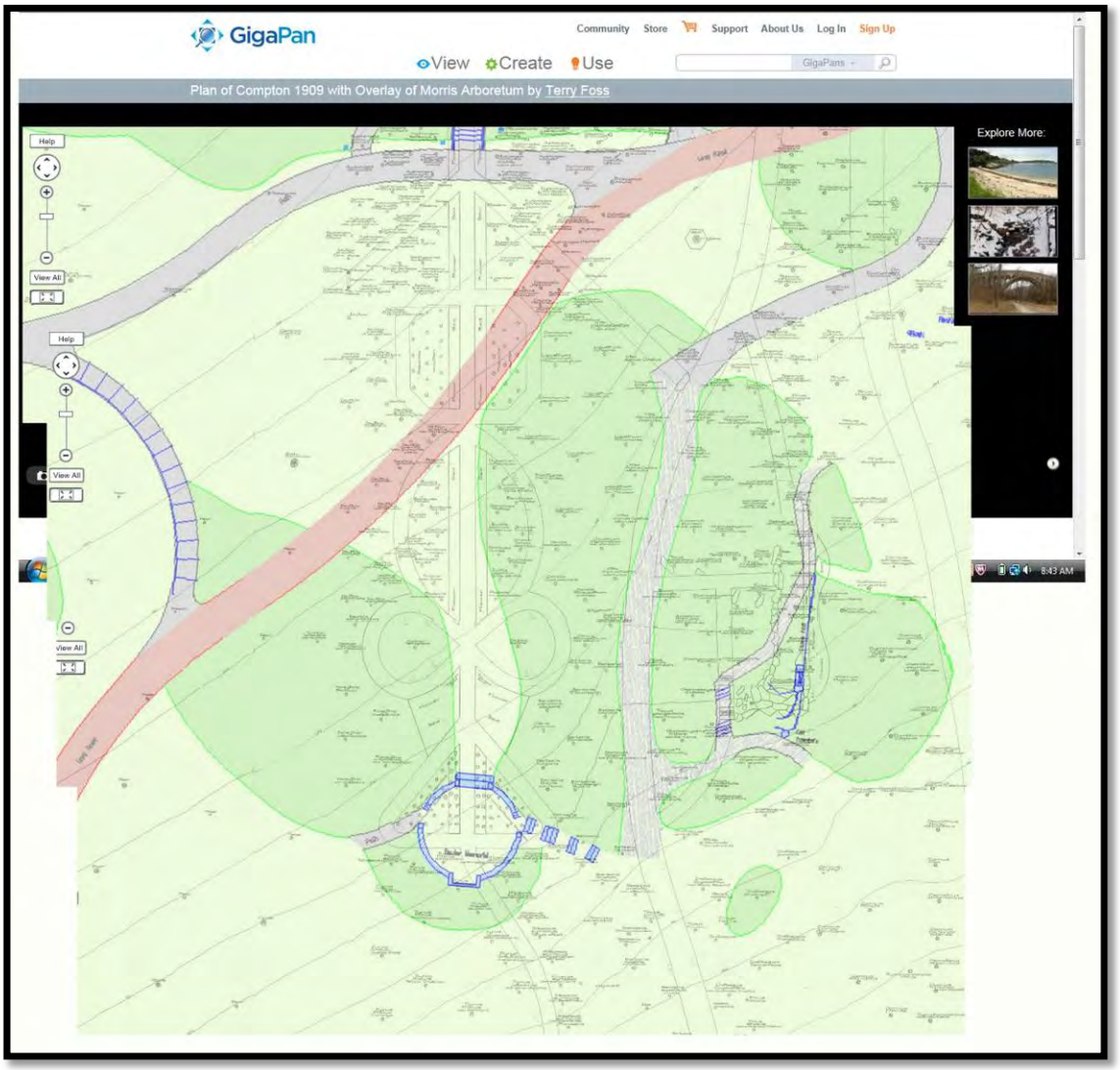


Flower Walk: 1909 Plan

1909 Planting Plan: #39

When restoring a site it is important to understand the context of its historic past. The objectives of reviewing John Morris's 1909 planting plans were to study the circulation, the plant collections, and if and how it could be relevant to today.

The pathways of the former flower walk cannot be recreated. This is due to the current circulation of the pathways, the location of the *Cedrus atlantica* 'Glauca', and the tree buffer of the *Magnolia*, *Pinus palustris* and the *Cryptomeria japonica*. A resting focal point as well as an area leading the eye out to the valley below is the ideal use of the space when viewing from the Pennock Garden. What has resulted from the research is to adapt the space to today's needs while still appreciating the context of the past.



Overlay of Current Arboretum plan with the 1909 Morris Garden

Baxter Memorial:

The Baxter Memorial was donated in 1947 by the Germantown Horticultural Society to honor respected Philadelphia horticulturalist and arborist Samuel Newman Baxter (32). He was the landscape gardener of the Fairmount Park system and later in his career became the chief arborist. This donation perhaps represents the first outside public connection with the Morris Arboretum.

The circle was to commemorate Baxter's contributions to Philadelphia horticulture. Among his accomplishments was "*Restoration of Plants in Bartram's Garden*" written by him for the Fairmount Park Commission of Philadelphia. This document was to record and provide direction for the historic plant collections at Bartram's Garden. Baxter also was part of a team that rediscovered and documented the Michaux Grove, which is located in West Fairmount Park.

In an article written by Margaret Lancaster in the Morris Arboretum Bulletin, published in October 1949, she describes the recently constructed Baxter Memorial. Dedication ceremonies occurred on June 5, 1948. "In a recess of the low balustrade is a durable cypress with a fitting inscription. The overlook is placed at the intersection of two paths, one to the rose garden through the orchard and the other leading up to the big hill through the Viburnum collection (32)." The article notes the views seen from the overlook area down to the valley were of a large wild cherry and a tall swamp cypress. One could view the evergreen collection up to the upper end of Hillcrest Avenue. The space was enclosed by the Crabapple Slope and by silverbells: *Halesia monticola* and *Halesia diptera*.

The article also documents the plantings and approximate locations at the site. American hollies were "to provide background for the overlook (32)." "A small ginkgo tree will form a future canopy for shade (32)." This Ginkgo (1935-6156*A) still remains at the site today, fully mature, providing the intended shade. There were low growing Cotoneasters provided from the large collection of Princeton University. These plants bordered the path leading down from the overlook. There were diversified plantings of boxwood donated by Colonel George Woodward. These consisted of *Buxus sempervirens* 'Suffruticosa', which "flanked the entrances." Additionally, plantings of *Buxus sinica* var. *insularis* (Korean box) created a border accenting the silverbell trees that framed the entrance. The article also references the planting of a bull bay (southern) Magnolia "in a warm and protected spot…if it survives it will be trained along the balustrade in the hope that its flower will scent this whole area (32)." Other plantings intended to grow on the balustrade posts are *Parthenicissus tricuspidata* 'Lowii', and *Decumaria barbara* "a climbing shrub native to our southern states (32)." This article aids in understanding what the space may have looked like in the 1950s and it is unknown how long some of these plantings lasted.

According to the Bulletin, on April 27, 1968, "Members of the Baxter family in the company of friends from the Germantown Horticultural society convened… for the purpose of dedicating a beautiful bronze direction finder in the Baxter Memorial terrace in memory of the late Mrs. Samuel Newman Baxter (33)." This is documenting when the plaque in the center of the circle was added in 1968. Volume 2, No. 4, Nov 1973, states that the children of Mr. and Mrs. Baxter donated funds for the cost of repairs and refurbishing the masonry work of the Baxter Memorial (34). Due to deterioration, the current Baxter Memorial poorly honors his memory, and does not clearly explain who he was, or what his contributions were to the Philadelphia region. Consideration was not taken to ensure the memorial blended with the Arboretum at the time of installation. The placement of the brick circle did not respect the existing "Flower Walk" gardens and selection of the brick as a building material does not match the materials used elsewhere in the Arboretum. While it is a quiet resting place for reflection, it no longer relates or connects to the surrounding spaces. The surrounding area and plantings have evolved and matured, but the memorial has not. Mature plantings have obstructed the entrances and steps. Most of the original plantings are no longer present such as the Cotoneaster and boxwoods. Views have changed as trees matured.

Existing Conditions:

After working in the garden for several months, observations related to safety hazards, circulation, and the need for seating and gathering space have been made. When first approaching the site in June 2012 initial thoughts "zeroed in" on the fragmentation and unorganized flow caused by the several unrelated and independent smaller spaces within the large space. The spaces are unwelcoming and do not provide a coherent visitor experience. For an educational garden with an interpretive sign, it would be beneficial for the sign and garden to relate to each other. The sign is titled "Pollinators in the Meadow Garden". The current garden does not educate visitors on pollination; the garden is not a meadow, and the plants portrayed on the sign are not present in the garden. The majority of plants currently are non-hardy, non-native annuals. They require watering two to three times a week during hot summer months. Most of the young shrubs planted on the outer ring of the south bed are in poor health. The plants in the three beds do not relate to each other on either side of the main pedestrian pathway.

The Baxter Memorial provides limited usage opportunities. The space is a *"pass through"* and when seated at the bench, there are limited views. The brick has deteriorated severely and the walls have collapsed in some areas. Formerly the Flower Walk created a strong axis from the orange balustrade to the Sundial Garden to today's Pennock Garden and now the eye is lead to the Baxter Memorial. The Memorial, however, was placed 6 feet off axis. The walls of the circle are blocking excellent views down to the valley and the Swan Pond from the stairs of the Pennock garden as well as from the main pathway/service drive. The stairs, which provide a connection for the Garden Railway, are a hazard for the public. There is no railing and they are uneven posing tripping hazards and are very uncomfortable to use.

Vegetation Analysis:

The vegetative analysis revealed the most valuable plants to take into consideration for redesign. This judgment is based on nativity, age, size, location for planned views, and focal points. The vegetative analysis is divided into four plans. The first plan is a combination of all layers: trees, understory/shrubs, and herbaceous layer. The second plan is the tree layer, the third is shrub/understory, and the fourth is the herbaceous layer. See appendix D for the existing plant inventory.

Tree Layer:

There are several specimen trees located along the exterior border of the space. The *Cedrus atlantica* 'Glauca' is a main focal point for the space and viewable from nearly every direction. The form and size of this tree creates an incredible impact for the space.

Additionally, specimen trees located in the Garden Railway tree buffer are beneficial for the space: *Magnolia grandifolia* 'Edith Bogue', *Cryptomeria japonica*, and *Pinus palustris*. This buffer is also a transition for the garden railway. There are opportunities for the buffer, such as an intimate space created between the *Magnolia* and the *Cryptomeria*. This space also provides one of the best views of the *Cedrus*. The crabapple slope is a border of the site and needs to be reconnected to space in the proposed design. Over the past decade several of the crabapples have been lost and need to be replaced.

In essence, the tree layer provides "walls" for the site, which creates the impression of a "room" when entering and passing through. There is no special transitional appearance when entering the space from the direction of the Rose/Cottage Garden. Therefore, it is an objective for the space to have a threshold and have plants of various heights to make the area a draw for visitors, yet meld with whole of the Arboretum.


T5
T3
T2
T25
T1
T4
T7
T16
T17
T24
T6

The Shrub-Understory Layer:

A feature of the space is the diverse *Hamamelis* (witchhazel) varieties that create incredible winter interest and structure.

The Rose Garden buffer contributes to the wall effect of the space by creating an edge. Some of these plantings can be thinned out to improve plant health and to aid in unifying and connecting spaces of the section.

There are young shrubs planted at the south side of the current meadow/pollination garden. These can easily be transplanted since they are in good health. In the northeast bed there is a mixture of shrubs, perennials, and annuals. The northwest bed is a mixture of perennials and annuals.

There is a group planting of *Ilex verticillata* and *Ilex verticillata* 'Red Sprite' oddly placed in the lawn creating an island effect for circulation in the space. The *Rosa* 'RadWhite' planted near the entrance of the Baxter Memorial are in poor health because they are not receiving enough sunlight.

The Herbaceous Layer:

This is the central focus of the space when passing through. The majority of perennial plantings from the 2009-10 additions to the south side of the garden did not survive (Appendix A). For the past few years annuals have been planted to fill many of the large gaps of space for the south side of

the garden. This is a temporary fix to fill in around the existing mix of shrubs and perennials.

There are very few plant species in the garden native to the U.S or Pennsylvania Of the approximate 90 plants within the borders of the analyzed site, approximately 20 are native to the U.S. and a few are native to the Piedmont.

The current site also has problems related to challenging weed species. The site is impacted by *Pinellia ternata*, creeping Charlie, English ivy, and Canada thistle, which are proving to be complicated to eradicate.

Topography, Hydrology and Aspects (Sun) Analysis:

Aspects (Sun):

The space is located on a gradual south-facing slope that is a very open and receives full sun. In the area around the Garden Railway Buffer and the *Ginkgo biloba*, there are periods of shade throughout the day.

Topography:

The overall slope for the site is 11.7% over a distance of 188 feet; this is a gradual slope, spanning from the upper path to below the Baxter Memorial. The northwest bed is a highly visual location, borders the main staircase, but experiences severe erosion due to its 15% slope.

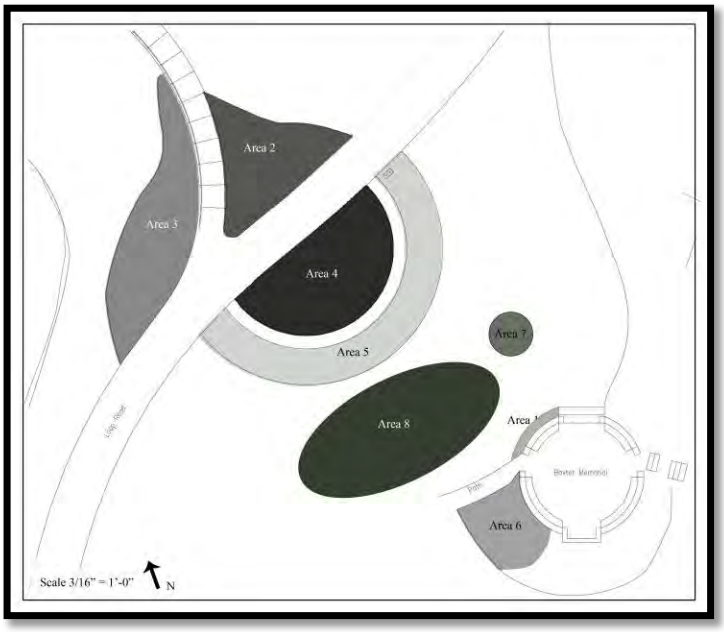
Hydrology:

Water movement through the space is at times a serious issue.

Water also travels down the pathway draining into the lawn near the crabapple slope close to the entrance/exit of the Rose Garden-Cottage Garden. There is no standing water or wet soils that would result from topography.

Soils Analysis:

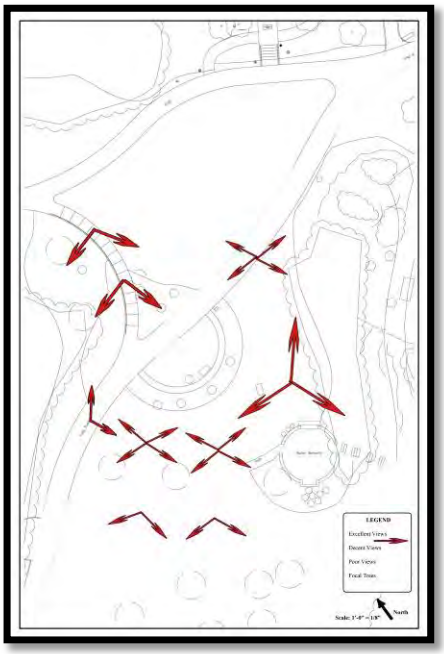
Soils samples were sent to the Penn State University extension, for the testing of eight different areas of the site in the fall of 2012 (Appendix B). Results yielded that seven of the areas had a pH range in the mid 7's, which is neutral leaning to the alkaline side. Area 3, the severely eroded slope, has a pH of 6.5.



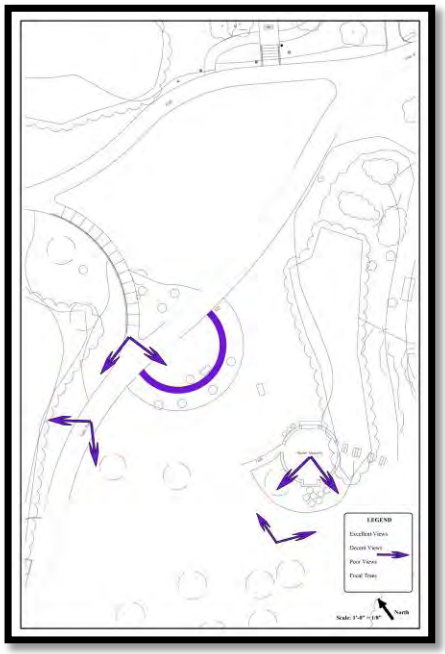
Views, Vistas, and Focal Points Analysis:

Views are often defined as “Features that create or allow a range of vision, which can be natural or designed and controlled (16).” Vistas are “A distant view or prospect, especially one seen through an opening, as between rows of buildings or trees. An avenue or other passage affording such a view (17).”

Several views throughout the space are intriguing and encourage exploration. As one approaches the stairs from the upper entrance path one immediately observes the *Cedrus atlantica* ‘Glauca’. As one descends down the stairs they see different angled views of the crabapple slope, which provides year-round interest. During the winter months one can see through the trees to the valley below and the Swan Pond. Along the buffer area there are “windows” or viewing spaces for Garden Railway watching. This concept can be expanded with strategic pruning and clearing of specific spaces for viewing the trains.



Excellent Views



Decent Views

Focal Points and Areas

When viewing the East Brook valley and the Swan Pond from the Baxter Memorial one has to stand along the wall. From here, there are views of trees providing year-round interest such as the *Prunus subhirtella* 'Pendula', *Taxodium disticum,* and *Chionanthus virginicus*. This view is obstructed by the brick wall and is limited to standing at the wall only.

Poor Views

Circulation Analysis:

Currently there is poor pedestrian flow and connection within the site and to its surrounding locations. As one travels from space to space, there is no formal connection or flow to each area. For example walking from the pollination garden to the Baxter Memorial and the Crabapple Slope, there is no designated or interesting pathway to experience the space.

The current Baxter Memorial has three entry/exit points, two of which have no pathway providing definitive connection to them. To access it one must walk through uneven lawn to the viewing area and bench. The stairs are a serious safety hazard for the public with uneven risers, no railings, and awkward

positioning. They do, however, provide a rear connection to the garden railway.

The current half circle pollination garden provides no interesting feature to entice a visitor to enter the garden. Additionally, the entire garden is viewable from the main pathway. The path is too narrow, uneven, unnecessary, and is not ADA accessible.

Opportunities and Constraints:

The results of the analysis phase led to the final analysis of opportunities and constraints. The site is divided into eleven areas; each area is analyzed based on its negative and positive attributes, which have been organized into a chart. Please reference the "Opportunities and Constraints" plan (Appendix B) and chart (Appendix C).

The site offers several design opportunities such as a space for a potential new seating area located in the niche between the *Magnolia grandiflora* 'Edith Bogue' and the *Cryptomeria*. This space is shady and provides an excellent view of the *Cedrus atlantica* 'Glauca'. Additionally, it provides up-close views of the trains and the Magnolia flowers when in bloom. This seating area is only installable pending the removal of Baxter Memorial.

There is the opportunity to have improved ADA accessible circulation and reestablish the connection through the crabapple slope to the Cottage-Rose Garden. Replacement of the stairs to the rear entrance/exit of the Garden Railway would be incredibly beneficial and aid in the safe, increased flow of foot traffic.

On the crabapple slope, several trees have died in the past several years. This is an opportunity for strategic replanting to occur. To improve the incorporation of the crabapple slope with the rest of the site fruit bearing trees such as Amelanchier or the native crabapple are proposed to aid with plant height dispersal.

RESEARCH PHASE

Case Studies/Landscape Architects/Design style:

Meadow Gardens

Meadow gardens are ideal for a landscape as they combine the best attributes of lawns and traditional borders. According to "The American Meadow Garden", they provide "a calming place for the eye to rest yet the richness and complexity of a border (1)." Meadows are healthier and more beneficial for the environment because "they provide safe habitat for beneficial insects and pollinators, a place where native ecology can thrive (1)."

Meadow gardens require less maintenance and utilize fewer resources than a lawn or border. Once established most meadows are drought tolerant. They are attractive and change with the seasons and hours of the day. The soils are not compacted and don't cause runoff of water unlike lawn that allows 80% of water to runoff (12). They do require maintenance to prevent succession of the eventual forest community. This is accomplished by mowing once a year (12).

Mount Cuba Center – Meadow Habitat Garden

The Mount Cuba Center Meadow Garden has been developed and maintained for twenty years by Meadow Horticulturalist Dave Korbonits. Discussed in his article, "Meadow Grasses are Lawn Alternatives, "A native meadow reestablishes the food web and aids in encouraging wildlife. (36)"

The plant palette is dominated with *Andropogon virginicus*: broom sedge, *Sorghastrum nutans*: yellow Indian grass and *Schizachyrium scoparium*: little bluestem, as the foundational grasses (36). Throughout the meadow there are accents of perennials such as: Asters, *Phlox*, *Rudbeckia*, *Eupatorium*, *Physostegia*, and *Asclepias*. Additional grasses such as: *Deschampsia cespitosa*, *Andropogon gerardii*, *Sporobolus heterolepis*, and *Muhlenbergia capillaris* provide diversity to the grass selection (36).

The entrance areas of the meadow are thoughtfully designed and more ornamental in appearance, then it transitions to the natural meadow. Maintenance is primarily focused on: invasive plant control, prevention of natural succession by removing woody plants and a yearly cut-back by mowing.

An applicable idea that can be utilized for the project is the more designed, ornamental approach of the entry areas of meadow garden. Another is the usage of native meadows plants of the Piedmont region.

Bowman's Hill: Native Plants and Meadow Garden

The four-acre meadow was started in 1998, prior to which it was mowed lawn. Seedlings were planted in the lawn and as the grasses matured, they out competed the lawn grass (14). The foundational grasses are bluestem, switchgrass, and Indian grass. Additionally, wildflowers such as the endangered mountain mint and other disturbance rich plant species are incorporated. The meadow also has trees such as red cedar, tulip poplar, river birch, black walnut and sycamore (14).

Applicable concepts from Bowman's Hill are native plants of the Piedmont region, in particular disturbance-rich ecological sites, the installation method, and the incorporation of endangered native plants.

Chicago's Millennium Park: The Lurie Garden; Designed by: Gustafson Guthrie Nichol Ltd, Piet Oldolf, and Robert Israel

The Lurie Garden is a fantastic example of the natural drift pattern described by Gary Smith, "a bold abstraction that symbolizes the prairie meadows of the American Midwest (7)." It is a five-acre representation of the prairie meadows of the American mid-west. It is a display of grasses, wildflowers, and spring bulbs that provide seasonal interest. Plant selection is both native and non-native and the composition is in drifts representing the natural dispersal of seed and spreading by runners (11).

Plant Selection: Native plants

According to Bringing Nature Home by Douglas Tallamy, seventy percent of the forests along the eastern seaboard no longer exist, thus creating fragmented landscapes and island effects (9). Small areas of habitat are left, but are too small to support diverse wildlife. One of

the best ways to remedy this situation today is to educate and encourage communities, commercial building projects, and private residences to install native plant habitats. Native plants of the Piedmont region are adapted to the climate, soils, and have evolved in this region for thousands of years (9). They have formed relationships with native insects and birds and provide pollination resources through: nectar, host, and seed. Birds are dependent on insects as food. With increased native plant habitat, insect populations can be increased and therefore, other wildlife can increase. In essence, creating habitat and increasing food availability supports the "food chain." Nearly every flowering native plant provides nectar/food for the native insects (9).

The ideal goal for the space is to create a meadow habitat garden. The plants selected are regionally appropriate and are "pioneer species", meaning they are found in early succession landscapes. According to Ian Caton of Larry Weaner Landscape Associates, during his presentation at the 2013 Land Ethics Symposium, plants that grow in riverside scour meadows are adaptable and are appropriate for a variety of sites. They are suitable to highly disturbed sites and periods of dry weather and would be appropriate for the meadow garden project (38).

This is an opportunity to select plants that are associated with specialist insects as a host or nectar source. These plants are vital for completion of the life cycle and aid in the increased diversity of a garden. The proposed plant list (appendix E) provides selections for planting and information regarding wildlife benefit.

PROPOSED DESIGN CONCEPT

The Philadelphia Native Plants Garden at the Morris Arboretum

Utilizing the analysis and research data, the proposed design is to create a garden to educate visitors of all ages about the evolutionary relationships between plants, pollinators, and wildlife. The design proposal is conceptual and identifies circulation, gathering/seating areas, and locations of trees and drifts of herbaceous plants. (The full-scale plans are located in the Morris Arboretum library). One of the most dramatic changes proposed for the space would be the decision to remove the Baxter Memorial.

A concern is how the removal of the brick circle will impact a highly valuable specimen, the *Ginkgo biloba*, a male tree, accessioned in 1935. Removing the memorial may benefit the tree by exposing the roots to more oxygen. Or the removal could potentially disturb the roots, which have developed under the brick patio.

The current "Pollination-Meadow Garden" concept will be continued. This is a strong educational message that can be enhanced by other components. With its close location to the Garden Railway, it is a high profile location in the Arboretum, meaning that visitation through the space will increase. This area can be a place to learn about the evolutionary relationship between plants, insects, and wildlife. It will be a semi-formal natural garden with perennials of varying heights mixed with grasses, shrubs, and understory trees. The same plant palette will be used for all the garden beds in order to have unity.

This garden area is an opportunity to display native plants of the Philadelphia region in a variety of combinations and bloom times. This garden can aid in the increase of insect

populations including: bees, predatory/biological, butterflies, hummingbirds, and other wildlife. These plants will provide nectar and/or host habitat. They will attract generalists and specialist insects and indirectly aid in the increase of bird population. Selections of plants were based on diversified bloom time, color, wildlife benefit, and the attraction of beneficial insects, butterflies, and birds

A re-design of the pollinator garden provides a way to demonstrate to the public how these plants can be incorporated in their home gardens. Currently the Rosarian, Lucy Dinsmore, is transitioning the lawn along the crabapple slope into a low growing meadow, which will better connect the space to the proposed native plants garden. Additionally, spring bulbs will be added to the existing clusters of bulbs on the crabapple slope to increase the spring show.

A new seating area and gathering space is proposed for the area in the niche between the *Magnolia grandiflora* 'Edith Bogue' and the *Cryptomeria japonica*. This area is shady during part of the day. Seating is limited in the Garden Railway so this creates opportunities for people to rest. This proposed seating area would be on axis with the Orange Balustrade, Sundial, and Pennock Gardens. It also provides a resting point for the eye before viewing the valley below. The seating area will have a memorial plaque for Samuel Baxter to educate the public on the history of his contributions. Circulation will be restored in the garden by the installation of a permanent meandering path to the rose garden. This path will have a widened curving entrance that travels through the crabapple slope, eventually connecting to the cottage/rose garden entrance/exit. A pathway will connect the main entrance staircase to the replaced stairs connecting to the Garden Railway. The new stairs installed will be with building codes and will be user friendly with unified risers and handrails.

<u>Theoretical Design Implementation:</u>

Year 1: Control of the *Pinnellia,* Canada thistle and other weeds.

Transplant or remove recommended non-native shrubs listed on plant inventory sheet

Remove: Baxter Memorial.

Grade areas for paths and seating area.

Begin no mow lawn and bulb plantings on crabapple slope and plant new crabapples.

Yr. 2: Layout paths and install new circulation. Plant new shrubs and understory trees

Yr. 3: Plant herbaceous plantings

CONCLUSION

The design site is filled with opportunities that will reflect the past and advance the space to the Arboretum of tomorrow. Redesigning this area is vital due to the high visual attention it receives. As one of the first and last areas viewed by visitors, it is imperative that the area be aesthetically pleasing, promotes a message that intrigues and inspires people to continue to learn more on their own after visitation at the Arboretum, and is a restful place for reflection with an open the view to the valley below when viewed from the Pennock Garden.

The project has covered a detailed analysis of the site and research on meadow gardens and native plants. It has provided comparative meadow gardens as case studies, research on pollination and native plant associations, plant selection for the site, and provided a proposed conceptual planting design. With this information the site has potential to become a place of gathering, seating, and a display garden for native plants. It can educate visitors on sustainable design through conservation of plants and water as well as provide education on endangered plants and sources for insect and bird attraction in the home garden.

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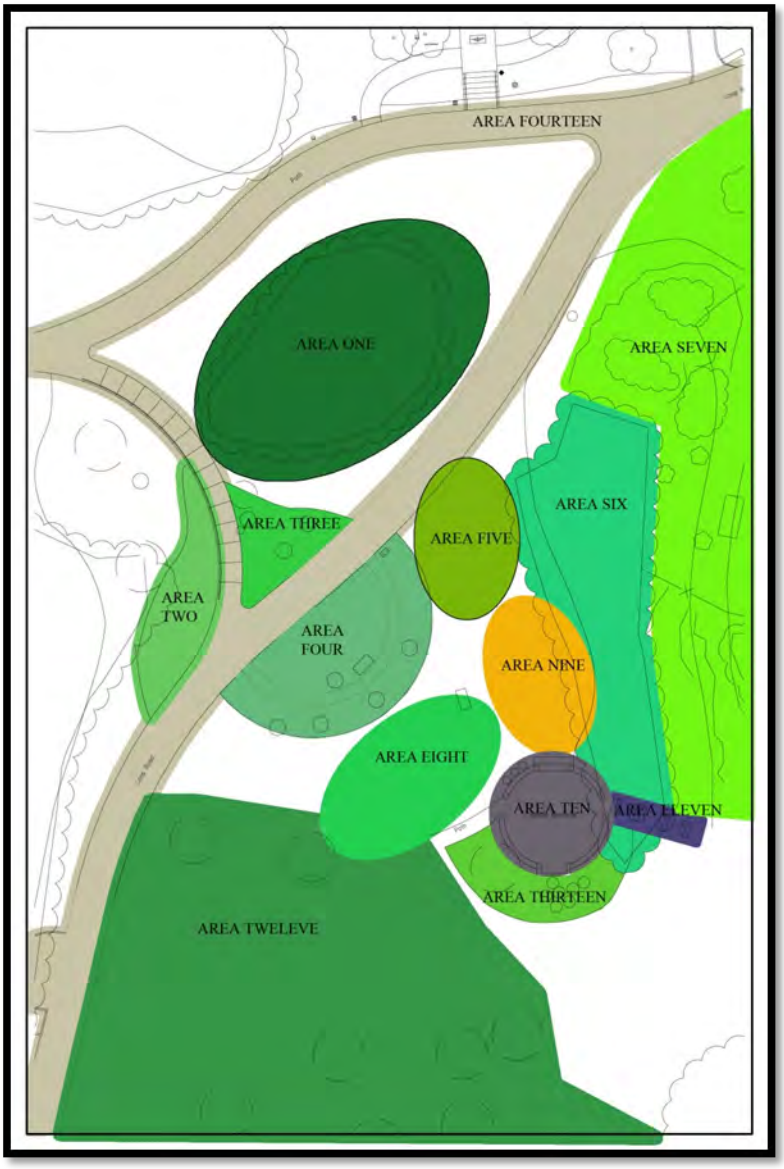
Appendices

Appendix A: Soil Analysis Results

SOIL ANALYSIS RESULTS

Area	pH	2P lb/A	EXCHANGEABLE CATIONS (meq/100g)					% Saturation of the CEC			Soil Nutrient levels	Recommendations
			3Acidity	2K	2Mg	2Ca	4CEC	K	Mg	Ca		
Area 1 Baxter Beds	7.2	248	0	0.3	5.2	17.7	20.5	1.6	25.4	73	Soil pH: optimum; Phosphate: below optimum; Potash: below optimum; Magnesium: above optimum; Calcium: above optimum	Since pH is greater than 7.0, use acid peat moss as the organic matter source if lower pH is sought.
Area 2 Pollination Garden Bed - North East	7.4	558	0	0.4	4.2	15.4	19.5	1.8	21.3	76.9	Soil pH: optimum; Phosphate: above optimum; Potash: below optimum; Magnesium: above optimum; Calcium: above optimum	Since pH is greater than 7.0, use acid peat moss as the organic matter source if lower pH is sought.
Area 3 Pollination Garden Bed - North West	6.5	60	3.4	0.4	2.1	5.4	11.3	3.5	18.8	47.6	Soil pH: below optimum; Phosphate: below optimum; Potash: below optimum; Magnesium: above optimum; Calcium: below optimum	CEC is below 15; add one inch of organic matter to raise the CEC. Add Calcitic Limestone - 7 lb/100 square feet
Area 4 Pollination Garden Bed - South-inner half circle	7.2	402	0	0.5	4.1	14.3	18.8	2.4	21.7	75.9	Soil pH: optimum; Phosphate: optimum; Potash: below optimum; Magnesium: above optimum; Calcium: above optimum	Since pH is greater than 7.0, use acid peat moss as the organic matter source if lower pH is sought.
Area 5 Pollination Garden Bed - South-outer half circle	7.1	654	0	0.4	4.9	15.8	20.3	2.1	24	74	Soil pH: below optimum; Phosphate: above optimum; Potash: below optimum; Magnesium: above optimum; Calcium: above optimum	Since pH is greater than 7.0, use acid peat moss as the organic matter source if lower pH is sought.
Area 6 Fern Bed next to Baxter Circle	7.2	184	0	0.5	3.7	10.8	15	3.1	24.8	72.1	Soil pH: optimum; Phosphate: below optimum; Potash: below optimum; Magnesium: above optimum; Calcium: optimum	Since pH is greater than 7.0, use acid peat moss as the organic matter source if lower pH is sought.
Area 7 Bed of Ilex verticillata	7	396	0	0.2	4.4	15.5	19.6	1.2	22.3	76.5	Soil pH: above optimum; Phosphate: optimum; Potash: below optimum; Magnesium: above optimum; Calcium: above optimum	Since pH is greater than 7.0, use acid peat moss as the organic matter source if lower pH is sought.
Area 8 Lawn between Baxter Circle and Pollination half circle beds	7.1	212	0	0.54	4.12	14.42	19.1	2.8	21.6	75.6	Soil pH: optimum; Phosphorus: optimum; Potassium: above optimum	Since pH is greater than 7.0, use acid peat moss as the organic matter source if lower pH is sought.

Appendix B: Opportunities and Constraints Plan



Appendix C: Opportunities and Constraints Area Chart

Area	Area Name	Opportunities	Constraints
Area One	Cedrus Atlantica 'Glauca'	Incredible focal point can be viewed from every direction	None
Area Two	North West Pollination bed	full sun dry soil loving plants. Expand bed along stairs and around trees. Create a new entrance area for the section.	extremely dry, clay soil experiences runnoff due to severely steep slope. Full sun year round.
Area Three	East Slope Bed	full sun dry soil loving plants. Expand bed along stairs and around trees. Opportunity to have Blue atlas as a background.	Existing plants, drought
Area Four	Half Circle Pollination Garden	Opportunity to redesign space, most of garden is annuals, this is an opportunity to create a new planting design. Have plant diversity. If shade is created, a seating could be placed. Interesting pathways.	No connection between spaces. Poor Circulation prevents flow. No appropriate seating area due to sun. 80% annuals. Currently a lack of height variety and no winter interest. Invasives: Pennelia, Thistle
Area Five	Proposed New Path Entrance/Exit	Ideally located to invite one into space.	none
Area Six	Buffer of Trees	Create observation areas into trains, and view trees and potential perennials. Garden railway attracts visitors this area. Add additional plantings.	creates a wall effect from the distance along path. Noise from garden railway.
Area Seven	Garden Railway	A major location for attracting vistors to the space. An opportunity to create a gathering seating area for vistors to enjoy.	Noise can be annoying for visitors.
Area Eight	Lawn Area	area for potential gathering or for creating a garden.	apart of the severe disconnect between spaces.
Area Nine	New Proposed seating area	Shade. Raised on slope. Fantastic view point in all directions. Private and enticing for people to sit.	closely located to Garden Railway, noise from trains can be heard.
Area Ten	Baxter Memorial	shade location. Seating area. Can reuse materials if removed. Readapt space area access way. A nice out of the way hidden"private" space for people to gather. Improve flow. A decent view of the woodland and swan pond/love temple when standing.	provides only one bench for people to sit. lack of good views in nearly all directions when sitting on bench. Very low down slope. 6' off axis of pennock orange balustrade. Location is tucked away from people rarely visited. Falling apart. Never endowed.
Area Eleven	Stairs	Opportunity to remove and create garden bed for improved health of ginko. Or restore them for access point	currently unsafe and awkward to use.
Area Twelve	Crabapple Slope	opportunity to invite people into space from several points. Plant new varieties to replace removed trees. An opportunity to connect spaces. Good focal points.	slope is not accessible to all vistors.
Area Thirteen	Garden on Baxter Slope	potential for garden area- boulders, grasses, succulents, etc. a positive view for the public, receives public viewing from pond and trains. Dry shade. Runoff (use in a benefitial way to slow water down hill.	steep slope, runoff, dry shade
Area Fourteen	Main Pathways	Provide connections between garden areas. Bring people into garden space	

Appendix D: Existing Vegetation Analysis

Existing Vegetation Analysis

Category	Latin Name	Common Name	Accession Number	Count (Perennials) When Applicable	Approximate Size at Maturity	Nativity or Cross Parentage	Notes	Location
Trees								
T1	Cornus kousa var. chinensis	Kousa Dogwood	96-590*A		15-30' T &W	Japan, Korea, China		Stairs Entrance
T2	Malus 'Indian Magic'	Flowering Crabapple	78-027*A		15-20' T x 8-10' W			Top of Stairs/Entrance
T3	Magnolia x soulangeana 'Brozzonii'	Saucer Magnolia	50-205*A		30' T	hybrid of *Magnolia heptapeta* x *Magnolia quinquepeta*		Top of Stairs/Entrance
T4	Cryptomeria japonica	Japanese Cryptomeria, Japanese Cedar	76-019*A		50-60' T, 20-30' W	Japan		Train Garden Buffer
T5	Cedrus atlantica var. 'glauca'	Blue Atlas Cedar	32-0303*A		40-60' T & W	Atlas Mountains of northwestern Africa		Intersection
T6	Ginkgo biloba	Ginkgo, Chinese Maidenhair Tree	35-6156*A		40'-80' T, 30'-40' W	East China		Baxter Circle/Buffer
T7	Magnolia grandiflora 'Edith Bogue'	Southern Magnolia	63-001*A		30' T, 20-30' W	South East U.S.	Most cold hardy selection, blooms in spring, white fragrance	Train Garden Buffer

T8	Malus 'Adams'	Flowering Crabapple	92-138*A	15’-20’ T	Crabapple Slope
T9	Malus 'Adams'	Flowering Crabapple	92-138*B	15’-20’T	Crabapple Slope
T10	Malus 'Auberine'	Flowering Crabapple	93-130*A	15’-20’T	Crabapple Slope
T11	Malus 'Centzam'	Flowering Crabapple	2000-156*A	15’-20’T	Crabapple Slope
T12	Malus 'Donald Wyman'	Flowering Crabapple	84-013*A	15’-20’T	Crabapple Slope
T13	Malus 'Donald Wyman'	Flowering Crabapple	84-013*B	15’-20’T	Crabapple Slope
T14	Malus 'Donald Wyman'	Flowering Crabapple	84-090-*B	15’-20’T	Crabapple Slope
T15	Malus 'Donald Wyman'	Flowering Crabapple	84-090*C	15’-20’T	Crabapple Slope
T16	Malus 'Indian Summer'	Flowering Crabapple	83-150*A	15’-20’T	Crabapple Slope
T17	Malus 'Indian Summer'	Flowering Crabapple	83-150*B	15’-20’T	Crabapple Slope
T18	Malus 'Jewelberry'	Flowering Crabapple	83-151*A	15’-20’T	Crabapple Slope
T19	Malus 'Jewelberry'	Flowering Crabapple	83-151*B	15’-20’T	Crabapple Slope
T20	Malus 'Red Jade'	Flowering Crabapple	93-251*A	15’-20’T	Crabapple Slope
T21	Malus 'Rambo'	Flowering Crabapple	99-007*A	15’-20’T	Crabapple Slope
T22	Malus 'Snowdrift'	Flowering Crabapple	77-036*A	15’-20’T	Crabapple Slope
T23	Malus 'Sutyzam'	Flowering Crabapple	92-139*A	15’-20’T	Crabapple Slope
T24	Malus 'White Angel'	Flowering Crabapple	77-032*A	15’-20’T	Crabapple Slope

T25	Pinus palustris	Longleaf Pine	34-4626-A	60-80' T, 30-40' W	Southern U.S. Native, zones: 7-10A		Train Garden Buffer
T26	Prunus mume	Japanese Apricot	2003-008*B		Japan	Southern Japan	Crabapple Slope

Shrubs

S1	Buddleja japonica	Butterfly Bush	Not Accessioned	4’ T & W	Japan	Removed, potentially invasive	North Bed
S2	Caryopteris x clandonensis 'Dark Knight'	Blue Beard	92-209*A	1.5’-2’ T&W	United States		North Bed
S3	Cornus sericea 'Cardinal'	Redtwig Dogwood	2002-053*A	7’ T-8’ W	United States		North Bed
S4	Cornus sericea 'Cardinal'	Redtwig Dogwood	2002-053*C	7’ T-8’ W	United States		North Bed
S5	Hamamelis x intermedia 'Rubin'	Witchhazel	2002-396*A	10’ T&W	Cross between H. japonica and H. mollis		North Bed
S6	Lespedeza bicolor	Bush Clover	93-366*A	8’ T&W	East Asia		North Bed
S7	Lespedeza bicolor	Bush Clover	93-366*B	8’ T&W	East Asia		North Bed
S8	Cornus sericea 'Bud's Yellow'	Buds Yellow Dogwood	2003-126*B	7’ T-8’W	United States		South Bed
S9	Rosa hugonis	Father Hugo Rose	98-226*A	7’ T & W	Chinese origins, parentage is unknown		South Bed
S10	Hydrangea arborescens	Smooth	2010-087*A	4’ T & W	Eastern		South Bed

	'Total Eclipse'	Hydrangea				United States		
S11	Weigela subsessilis 'Canary'	Weigela	2000-156*A		5’ T & W	Japan, Korea		South Bed
S12	Hamamelis x intermedia 'Danny'	Witchhazel	2004-034*A		15-20’ T	Cross between H. japonica and H. mollis		South Bed
S13	Rosa hugonis?	Father Hugo Rose	Not Accessioned		7’ T & W	Chinese origins, parentage is unknown		South Bed
S14	Hypericum frondosum ‘Sunburst’	St. John's Wort	Not Accessioned		2.5’ T, 4’ W	United States		South Bed
S15	Buddleja japonica	Butterfly Bush	Not Accessioned	3 plants	4’ T & W		Removed, potentially invasive	South Bed
S16	Paeonia suffruticosa 'unknown species'	Tree Peony	Not Accessioned		4’ T & W	China, Tibet, Bhutan		South Bed
S17	Lespedeza bicolor	Bush Clover	Not Accessioned		8’ T & W	East Asia		West Bed
S18	Vitex agnus-castus	Chastetree	Not Accessioned		8’ T, 6’ W	Southern United States		West Bed
S19	Hamamelis x intermedia 'Primavera'	Witchhazel	2002-395*B		12’ T & W	Cross between H. japonica and H. mollis		North Stair Case East Side
S20	Hamamelis vernalis 'KLMnineteen'	Witchhazel	2008-135*A		6’ T, 8’ W	United States		North Stair Case West Side
S21	Ilex verticillata	Winterberry	2002-142*A		6’ T, 8’ W	United States		Open Lawn

		Holly						Area
S22	Ilex verticillata 'Red Sprite'	Winterberry Holly	89-122*A	MASS	6’ T, 8’ W	United States		Open Lawn Area
S23	Rosa 'RADwhite'	Whiteout Rose	2010-099*A	3 plants in group	3.5’ T & W			Baxter Memorial Circle
S24	Ilex x meserveae 'Mesog' CHINA GIRL	Meserve Holly, Blue Holly	2007-049*A	5 plants in group	8’ T, 6’ W	Cross between I. rugosa and I. aquifolium		Baxter Memorial Circle
S25	Ilex x meserveae 'Mesdob' CHINA BOY	Meserve Holly, Blue Holly	2007-048*A		8’ T, 6’ W	Cross between I. rugosa and I. aquifolium		Baxter Memorial Circle
S26	Rosa 'Madame Plantier'	Madame Plantier Rose, The Brides Rose	94-177*A		5’ T & W	Cross between an alba rose and Rosa moschata	Classified as an Alba, Noisette an Old Garden Rose	Crabapple Slope
S26	Chimonanthus praecox	Fragrant Wintersweet	49-546*A		10’ T	China		Rose Garden Buffer Bed
S27	Corylopsis pauciflora	Winterhazel	2002-348*A		5’ T & W	Japan and Taiwan		Rose Garden Buffer Bed
S28	Corylopsis pauciflora	Winterhazel	2002-348*B		5’ T & W	Japan and Taiwan		Rose Garden Buffer Bed
S29	Corylopsis pauciflora	Winterhazel	2002-348*C		5’ T & W	Japan and Taiwan		Rose Garden Buffer Bed
S30	Rhododendron metternichii 'Oki Island'	Rhododendron	86-280*D		Unknown	Japan	Rare in cultivation	Rose Garden Buffer Bed
S31	Syringa 'Purple Haze'	Purple Haze Lilac	2005-125*A		8’ T & W	Cross of S. oblata and S. protolaciniata		Rose Garden Buffer Bed
S32	Syringa 'Purple Haze'	Purple Haze Lilac	2005-125*B		8’ T & W	Cross of S. oblata and S.		Rose Garden Buffer Bed

						protolaciniata		
S33	Syringa vulgaris 'Nadezhda'	Nadezhda Lilac	93-152*B		8’ T & W	Southern Europe, Introduction from Russia		Rose Garden Buffer Bed
S34	Syringa vulgaris 'Nadezhda'	Nadezhda Lilac	93-152*A		8’ T & W	Southern Europe, Introduction from Russia		Rose Garden Buffer Bed
S35	Cotoneaster multiflorus	Cotoneaster	2002-314*A	5	10’ T & W	Western China		Rose Garden Buffer Bed
S36	Pieris japonica 'Variegata'	Japanese Pieris	2000-100*A		3-4’ T & W	Japan, Taiwan, Eastern China		Train Garden Buffer
S37	Corylopsis glabrescens	Fragrant Winterhazel	87-116*B		12’ T & W	Japan		Train Garden Buffer
S38	Hydrangea anomala ssp. petiolaris	Climbing Hydrangea	32-0080*A		25’ T, 6’ W	Japan, China		Train Garden Buffer
Perennials								
H1	Achillea 'Terra Cotta'	Yarrow			2.5’ T & W	Europe		South Bed inner bed
H2	Amsonia hubrichtii	Blue Star			3’ T & W	Central-Southern United States		South Bed inner bed
H3	Allium cernuum	Nodding Onion			1.5’ T, .5’ W	North America	Dry to moist prairies, stream banks. 7.2 pH. Valuable to bees and biological control	South Bed inner and outer beds

						insects.	
H4	Aquilegia canadensis	Canadian Columbine		2’ T&W	North America		South Bed outer bed
H5	Chasmanthium latifolium	Northern Sea Oats		3.5’ T, 2’ W	North America		South Bed inner and outer beds
H6	Coreopsis lanceolata	Lanceleaf, Tickseed		2’ T, 2’ W	North America		South Bed inner bed
H7	Eupatorium dubium 'Little Joe'	Joe Pye Weed		3.5’ T, 1’ W	Northeast United States		South Bed inner bed
H8	Helianthus augustifolius 'Gold Lace'	Swamp Sunflower		7’ T, 5’ W	North America	Not as aggressive when planted in dry soil	South Bed inner bed
H9	Iris	Bearded Iris		8”-2.5’ T, 1.5’ W	Europe		South Bed outer bed
H10	Iris siberica 'Caesar's Brother'	Siberian Iris		3’ T&W	Eastern Europe	Prefers moist conditions	South Bed outer bed
H11	Lilium lancifolium var. 'fortunei'	Oriental Lily or Easter Lily		3.5’ T	Eastern Guam, China, Korea and Japan		South Bed inner and outer bed
H12	Pennisetum alopecuroides 'Foxtrot'	Foxtrot Fountain Grass	One cluster of 3	4’ T&W	Eastern Asia to Western Australia		South Bed inner
H13	Pennisetum alopecuroides 'Foxtrot'	Foxtrot Fountain Grass	One cluster of 5	4’ T&W	Eastern Asia to Western Australia		South Bed outer
H14	Crocosmia 'Lucifer'	Crocosmia		3’ T, 2’ W	Temperate Southern Africa		
H15	Paeonia sp.	Peony		3’ T & W	China		

H16	Kniphofia hirsuta 'Fire Dance'	Red Hot Poker	1.5’ T & W	Native to South Africa		West Bed
H17	Amsonia hubrichtii	Blue Star	3’ T&W	Central-South United States		West Bed
H18	Coreopsis lanceolata	Lanceleaf, Tickseed	2’ T, 2’ W	North America		West Bed
H19	Solidago rugosa 'Fireworks'	Fireworks Goldrod	3’ T& W	North America		West Bed
H20	Aquilegia canadensis	Canadian Columbine	2’ T&W	North America		West Bed
H21	Geranium sanguineum var. 'Striatum'	Bloody Cranesbill	1’ T&W	Great Britain (Walney Island, Cumbria)		North Bed
H22	Penstemon digitalis 'Husker Red'	Husker Red Penstemon	2’ T & W	North America	Not a local native	North Bed
H23	Iris siberica 'Caesar's Brother'	Siberian Iris	3’ T&W	Eastern Europe		North Bed
H24	Rudbeckia fulgida	Black Eyed Susan	2.5’ T&W	North America		North Bed
H25	Pennisetum alopecuroides 'Foxtrot'	Foxtrot Fountain Grass	4’ T&W	Eastern Asia to Western Australia		North Bed
H26	Amsonia hubrichtii	Blue Star	3’ T&W	North America		North Bed
H27	Sporobolus heterolepis	Prairie Dropseed	3’ T&W	North America	Not a local native	North Bed

TITLE: **A COMPARISON OF EXTANT VEGETATION TO THE SOIL SEED BANK IN THE NATURAL LANDS SECTION OF THE MORRIS ARBORETUM**

AUTHOR: **Emma C. Williams**
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DATE: **June 2013**

ABSTRACT:

Current management goals of the natural lands section of the Morris Arboretum revolve heavily around invasive species control. One of the most prolific invaders is reed canarygrass (*Phalaris arundinacea*), a cool season perennial grass. Reed canarygrass has formed a dense stand in a section of the meadow that experiences seasonal inundation of Wissahickon Creek flood waters and is occurring in adjacent areas within the floodplain meadow. Heavy seeding and planting with natives is recommended following removal of *P. arundinacea* to prevent re-establishment through competition (Wisconsin Reed Canary Grass Management Working Group, 2009).

This project seeks to quantify and compare the species composition of the extant vegetation and the soil seed bank to assess environmental sources of native viable propagules for restoration. Species richness and relative percent cover were measured in plots placed in both the reed canarygrass dominated and adjacent uninvaded areas in the floodplain as well as the sloping upland section of meadow. Associated soil cores were collected at 5-cm depth increments to 15-cm, cold stratified, and assayed for viable seed in a controlled greenhouse. Viable seed reduced with depth in the soil column. Seed samples from the reed canarygrass section of the meadow exhibited higher species richness than the associated extant vegetation and canarygrass seedling abundance reduced with depth. This data on the composition of the soil seed bank are integral to developing appropriate management actions designed to promote target restoration species while controlling invasives.

A Comparison of Extant Vegetation to the Soil Seed Bank in the Natural Lands Section of the Morris Arboretum

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INTRODUCTION

An overarching ecological goal of the natural lands section west of Northwestern Avenue at the Morris Arboretum is to increase biodiversity of flora and fauna. Current management strategies geared to meeting this goal revolve heavily around invasive species control. *Phragmites australis, Typha spp., Phalaris arundinacea,Gallega officinalis,* and *Cirsium arvense* are the predominant invaders in the meadows, where they out compete native plants and alter wildlife habitat. Roughly 2.5-acres of the floodplain meadow are invaded by *P. arundinacea.* This cool season perennial grass invades using "phalanx strategy, where tillers mass into an impenetrable clone expanding over short distances, [and]…a guerilla strategy, where the parent plant forms long rhizomes and new tillers emerge at a distance from the parent clone (Wisconsin Reed Canary Grass Management Working Group, 2009)." These strategies are successful at competing with native and non-native species, which leads to reduced floral biodiversity; the result is a dense stand of *P. arundinacea* with very few associated species. Decrease in plant species diversity is generally acknowledged to result in decreased habitat diversity for wildlife.

Heavy seeding and planting with natives is recommended following removal of *P. arundinacea* to prevent re-establishment through competition (Wisconsin Reed Canary Grass Management Working Group, 2009). Seeding is not currently employed in the natural lands section due to budgetary and resource limitations, leaving the seed bank as the source of regeneration controlled areas (T. Beerly, 2012). Because the invaded areas have been dominated by *P. arundinacea* for an extended period, it is difficult to infer the species composition of the seed bank. Determining the contents of the soil seed bank could inform management decisions intended to promote germination and establishment of target species (Bossuyt & Honnay, 2008).

There is little documented information on the plant species currently inhabiting the natural lands section. A thorough species inventory will provide a baseline of the current status of the plant community, giving managers insight into the vegetative resources the area possesses. This project provides a list of extant and seed bank species occurring in three areas of the natural lands section and their associated seed bank—comparing areas heavily dominated by invasive *P. arundinacea* with those in which a more diverse assemblage of species occurs. These areas, mapped in Appendix A, are defined as the upland sheep meadow, the floodplain entrance meadow (south-west of the entry driveway), and the floodplain grass meadow (dominated by *P. arundinacea*). In addition, I compiled a specimen reference collection and a photo documentation file of seedlings from each species in the seed bank. These resources will be available at the Morris Arboretum herbarium and on the staff shared drive, respectively, with the intended goal that target species will be more easily identifiable at an early developmental stage by Arboretum section leaders.

A.G. van der Valk and R.L. Pederson state "Vegetation management, based on the exploitation of seed banks, will be successful only when (1) the seeds of the required or preferred species are present in the seed bank, (2) the seeds of unwanted species are not present or, at least, are uncommon, and (3) conditions suitable for the germination of the seeds of preferred species can be established and maintained (Leck et. Al, 1989). When these conditions are met, using knowledge of germination requirements, managers have been able to successfully create conditions selecting for target species or against undesirables. The data produced in this paper is

aimed to establish the composition of the soil seed bank, and associated extant propagule sources, for use by current and future managers. I designed this project to answer three primary research questions: 1) is species composition of the soil seed bank similar to that of the respective extant vegetation? 2) does species richness in the soil seed bank change with depth? 3) is there a source of native plant propagules in the *Phalaris* dominated area of the natural lands section?

METHODS

Site Description

Three areas of the meadow were selected, based on an informal survey, for apparent diversity of vegetation with the intent of selecting for the highest species richness and a more inclusive species inventory. Two sites were selected within the floodplain of the Wissahickon Creek and one was selected on an adjacent upland slope. Both of the floodplain sites receive annual floodwater inundation that provides a source of flood dispersed seed and vegetative propagules. The floodplain grass meadow (FG) plots lie nearest to Wissahickon Creek, between the wetland pond to the west and Papermill Run to the east. This section is dominated by a relatively homogenous stand of *Phalaris arundinacea* and *Urtica dioica*. The floodplain entrance meadow plots (FH) are located south of the Arboretum's entrance driveway and west of Papermill Run. The plots were placed deliberately with the intent of including both the lowest cover of *P. arundinacea* and highest number of patches of differing dominant species, suggesting a comparable reference condition of a meadow not receiving *P. arundinacea* seed rain. One plot is dominated by *Solidago spp* and *Rubus pennsylvanica,* another by *Carex spp* and *Juncus tenuis*, and another by *Artemesia vulgaris* and *Apocynum canabinum*. To include further species composition comparison, the upland sheep meadow (UH) plots were placed on the north-west facing slope above the floodplain, north of the section of driveway directly below the magnolia slope.

Survey of Extant Vegetation

The respective areas of the natural lands section were surveyed within 3 100-m^2 square plots delineated with flagged fence posts. The plots were gridded into 100 quadrats of which 12 were randomly selected for data collection. The northern most quadrat was noted as the origin with a value of 1-A. Each quadrat was sampled once in July and August of 2012 and again in May 2013 for species richness, composition, and total percent canopy cover of each species. Species identification and verification assistance was provided by Arboretum senior botanist Ann Rhoads. Vegetative propagules of *Rununculus ficaria*, which does not reproduce by seed, were not measured for canopy cover but were surveyed as present or absent in the summer and propagule abundance was measured during the seed bank assay. A specimen of each identified species growing with the plots was pressed, mounted, entered into the Flora of Pennsylvania database, and will be filed in the Morris Arboretum herbarium as a reference collection of the natural lands section flora.

Soil Seed Bank Assay

Species richness, composition, and abundance of the soil seed bank was quantified by performing a soil seed bank assay. Soil cores were collected from each extant vegetation survey plot following late season seed dispersal in October, 2012. I extracted the cores using a 6-cm

diameter tulip bulb planter to a depth of 15-cm. Each core was separated into 3 depth increments of 0-5cm, 5-10cm, and 10-15cm from the soil surface to yield three ~150-cm^3 soil samples per quadrat. Roughly 10-mg of water was added to each soil sample before placing them into a growth chamber at 2-5°C for 72 days of cold stratification to break dormancy. The stratification period was designed to meet the dormancy breaking requirements of the greatest number of species within the time limitations (Baskin and Baskin, 1998).

Vegetative propagules were removed from the samples using a .25-cm gauge sieve. Rhizomes and *Ranunculus ficaria* tubers were counted and discarded. Each soil sample was distributed into a 4-cm by 6-cm potting tray atop 2-in of 3B potting media. The collected soil volume was pre-determined to insure no more than 1-cm of sample soil was placed in a tray so seeds would receive enough light to meet their germination requirements (Adams & Steigerwalt, 2008). Soil was watered daily and nematodes were added to manage for expected thrip larvae. Emerging seedlings were identified to most specific taxonomic level possible, photographed, vouchered as herbarium specimens, counted, recorded, and removed. Particularly prolific species were assigned a code if not identifiable; an individual was then transplanted for further development and later identification while the remaining individuals were counted and removed to reduce competition within samples. Photodocumentation of natural land section species seedlings will be compiled and deposited on the Morris Arboretum shared drive for the use and knowledge of section leaders. Standard formatting of the file name of each photograph is as follows: SPECIESCODE_ECW_DATEPHOTOGRAPHED. Species codes are consistent with the USDA plants database. Specimen vouchers of seedlings will be deposited into the Morris Arboretum herbarium as a reference collection of the natural lands section flora.

Data Analysis

Similarity of species composition between the soil and extant flora was quantified using Jaccard's Index of Similarity. The index yields a proportional value with an output of one representing the occurrence of all species in both the seed bank and extant vegetation and a value of zero signifying no species in common. The presence of species was pooled within each plot for comparison before pooling the plots into a meadow area comparison.

RESULTS

In the late winter months, the upland sheep meadow plot markers were removed during a mowing event. I replaced where I believed to be the remnant post holes with markers and based my spring extant vegetation survey on these markers. In the spring, markers in one of the floodplain entrance plots were removed and I remarked the plot using a mix of recollection, plot photographs, and the location of extant perennials recorded during the summer vegetation survey.

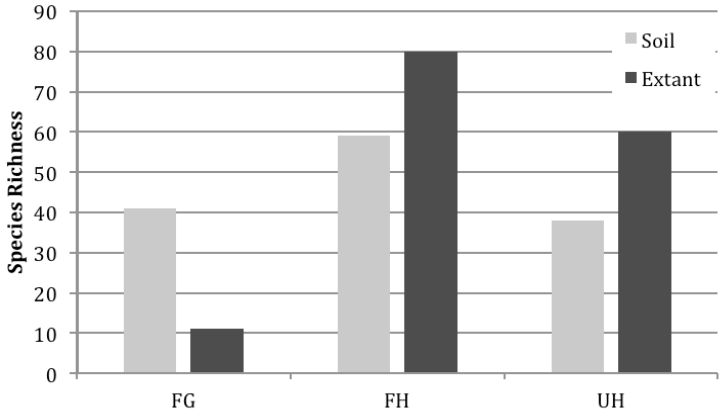

Figure1: Total Species Richness of Extant Vegetation and Seed Bank

The potential for mis-marking the replacement plots creates additional uncertainty in the data. Total species richness, the number of species present, of the soil seed bank in the floodplain grass (FG) plots exceeded that of its extant vegetation while the seed bank richness values of the FH and UH plots were lower than their extant richness. The FH meadow area contained the greatest species richness in both the combined spring and summer extant vegetation and the soil seed bank (Figure 1).

Mean species richness of the FG seed bank was lower at each depth increment with a negative difference of one species from the surface sample to the 10-cm depth.

The FH plots yielded the highest number of total species with richness decreasing by two species with each 5-cm depth increment from the surface. The UH area seed bank richness also decreased with depth, by 3 and 2.3 species from the surface to 5-cm and 5-cm to 10-cm depths, respectively (Figure 2). Average density of germinable seed per soil sample decreased with depth in all areas of the meadow. The UH samples contained the greatest number of viable seed at the surface depth, but, germination declined at the 10-cm depth to an abundance even with that of the FH plot. The FG samples contained relatively fewer seedlings at each depth than the other two meadow areas. Each sampled community contained high variability in germinable seed abundance (Figure 3).

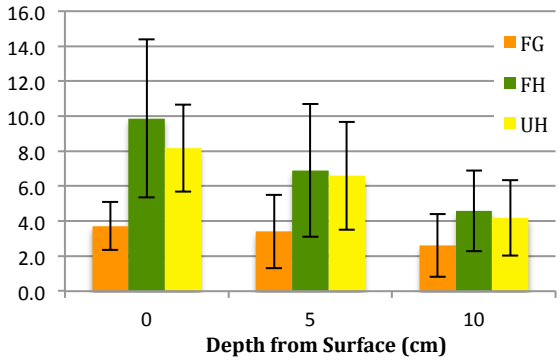

Figure 2: Mean Species Richness of Seed Bank

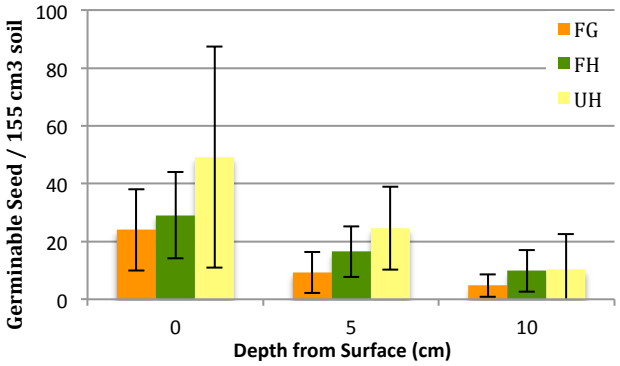

Figure 3: Mean Seed Density of Seed Bank

The effort to remove vegetative propagules through sieving the soil samples was assumed to incidentally remove large seeded species. Species producing a mean seed diameter greater than 3-mm were withheld from Jaccard's similarity comparison to reduce bias of false negative absences; in addition, *Rubus pennsylvanicus* was withheld due to unmet germination requirements. The similarity of species composition of the soil seed bank compared to the extant vegetation was lowest in in the FG plots (Figure 4). The similarity indices of the FH and UH plots were close to each other at each depth. Jaccard's similarity coefficient decreased with depth in the FH and UH sample while remaining constant in the FG sample.

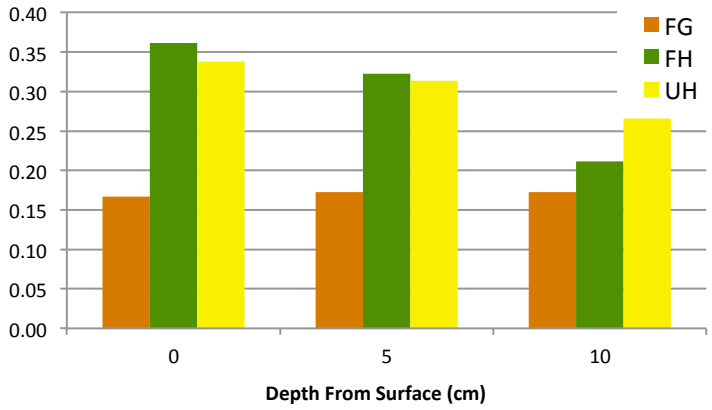

Figure 4: Jaccard's Similarity Index of Seed Bank to Extant

Total species abundance of

germinated seed is charted in Appendix B. Of the total 6, 104 seedlings germinating from the soil seed bank samples, the UH plots contained the greatest proportion while the FG contained the fewest (Table 1). *Phalaris arundinacea, Oxalis stricta*, and *Solidago sp* were the most abundant taxa germinating in the FG, FH, and UH soil samples, respectively. The mean abundance of *Phalaris arundinacea* in the seed bank strongly decreased from the surface to 5-cm depth (Figure 5).

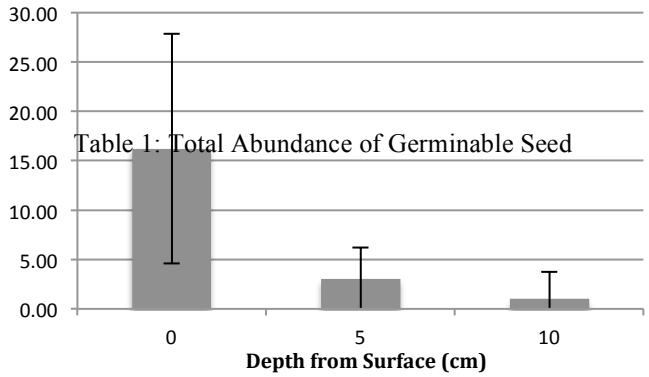

Figure 5: Mean *P. arundinacea* abundance in FG

Table 1: Total Abundance of Germinable Seed

Sample Area	Total Germinable Seed
FG	1362
FH	1821
UH	2921
Total	6104

DISCUSSION

Review of seed bank studies across European habitats has indicated that seed banks may be a tool for restorations in plant communities undergoing disturbance (Bossuy & Honnay, 2008). The Morris Arboretum natural lands section currently employs an annual mowing regime. The standing biomass, once cut, is left as duff—leaving the associated reproductive structures on site. By determining the composition and relative abundance of the soil seed bank, in comparison to the extant vegetation, one can infer the potential future composition and begin to determine whether target species are becoming established from the seed bank or if alternative management strategies are needed (Adams & Steigerwalt, 2008; Leck, 1989).

The low Jaccard similarity value for the FG plots is a result of a majority of species present in the seed bank not being present in the extant vegetation. A plant canopy and standing or fallen litter can reduce significantly, or prevent completely, the recruitment of species from the seed bank (Leck, 1989). In the FG area of the meadow, the dense canopy cover *of Phalaris arundinacea* may be contributing to the relatively low species richness expressed in the extant vegetation while a greater richness of viable seed rests in the soil. The Jaccard similarity values for the FH at depths 0-cm (.36) and 5-cm (.32) and the UH at depths 0-cm (.34) and 5-cm (.31) were comparable to earlier studies of European grasslands (Bossuyt & Honnay, 2008). The Bossuyt and Honnay study found that the Jaccard similarity values for grasslands were higher than forests.

Seeds that remain viable in the soil for one or more years are defined as comprising the persistent seed bank, while those remaining viable for less than a year comprise the transient seed bank (Baskin & Baskin, 1998). In this study, the transient seed bank is captured only in the top 5-cm of soil. The reduction in species richness with depth may be due to the loss in viability of persistent seeded species with relatively low seed longevity and species of the transient seed bank. This may also account for higher seed bank to extant similarity values near the surface.

High variability in seedling abundance

was largely due to relatively few samples containing a large sum of seedlings of an individual annual species. For example, one surface sample in the UH section contained 164 individuals of *Cardamine hirsuita*.

CONCLUSIONS

The knowledge of botanical resources in a meadow can assist in projecting the trajectory of secondary succession (Bossuyt et. al., 2008). The differences between the species present in the soil seed bank to those present in the extant vegetation prohibits a manager from being able to accurately infer the composition of one based on knowledge of the other. Plots placed in the area dominated by *Phalaris arundinacea* were found to contain comparable species richness to those on the upland slope. The overwhelming abundance of this species in the seed bank allows managers to infer that there is high potential for reoccurring recruitment of *P. arundinacea* with low potential for other species. When the invader of a system has reached a saturation point, *as P. arundinacea* apparently has in this area, eradication is generally not the most feasible alternative (Callaham, 2006). While the evident decrease in biodiversity of the natural lands section in the FG reduces both the educational value for native plant identification and wildlife habitat diversity, the immense resources required to remove the *P. arundinacea* may be counter productive at this time. Energies focused on monitoring and treating patches of the grass in the FH area of the meadow may promote increased and sustained diversity of flora. If control of *P. arundinacea* is pursued in the FG area, I recommend integrating an aggressive seeding and planting strategy to promote rapid establishment of target vegetation.

Due to the effort required to provide complete and consistent results while conducting the soil seed bank assay, I was unable to spend the time necessary in the spring to conduct a complete species inventory of the natural land section. The species listed in Appendix C can augment current inventory efforts and can help to focus future surveys. A comprehensive species list is an important tool for management of an area and also provides opportunities for education. Currently, there is little information available to visitors on the contents of the natural areas meadow. Making the survey list available to the public would encourage more critical engagement with and a wider understanding of Pennsylvania's flora.

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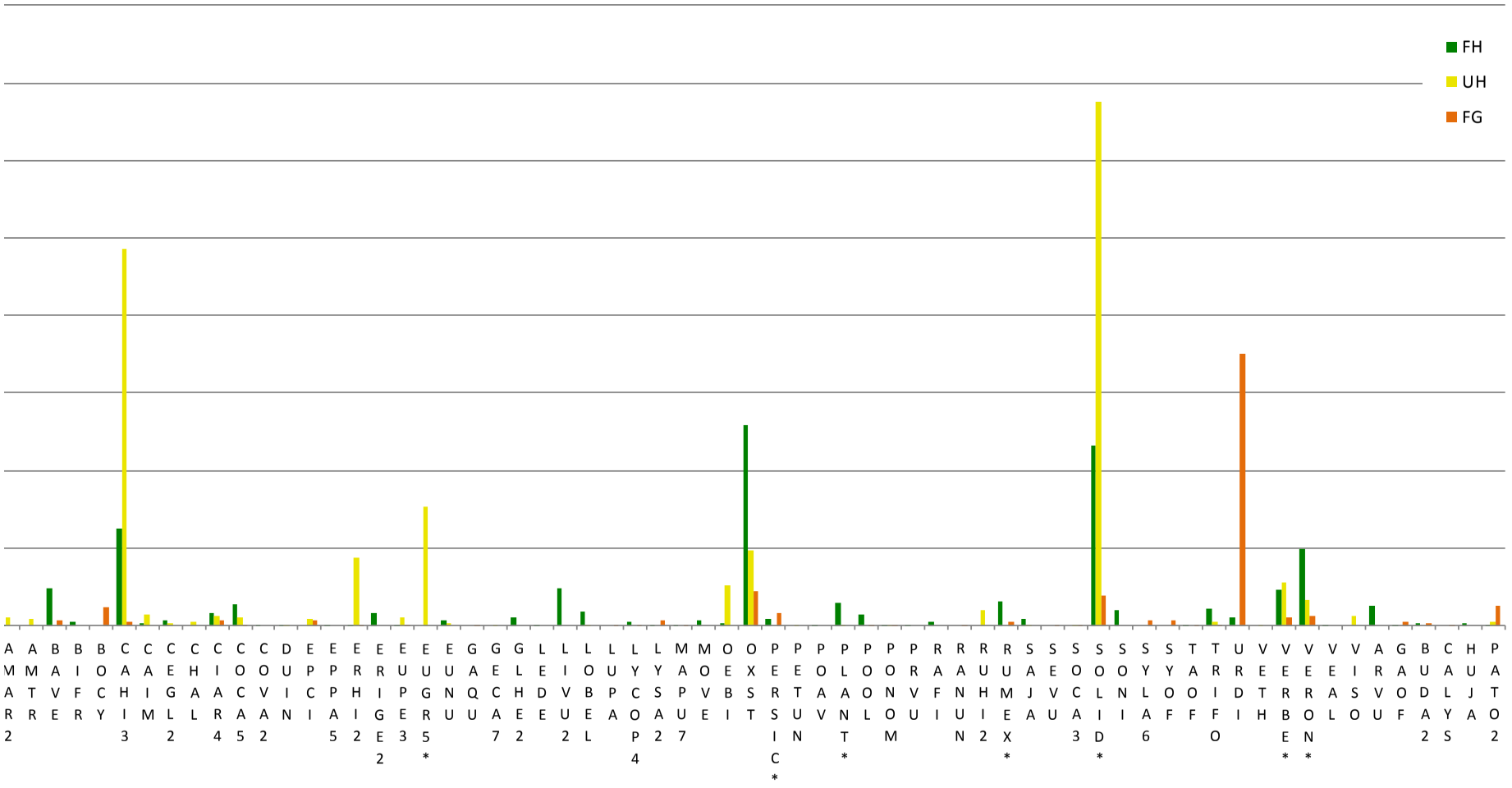
APPENDIX A:

Map of Study Sites



APPENDIX B: Species Abundance in Soil Seed Bank

APPENDIX C:
Species Compendium of Extant Vegetation

Forbs	
Symbol	**Latin Name**
ACRH	*Acalypha rhomboidea*
AGERA2	*Ageratina*
AGAL5	*Ageratina altissima*
AGGR2	*Agrimonia gryposepala*
ALPE4	*Alliaria petiolata*
ALLIU	*Allium sp*
AMAR2	*Ambrosia artemisiifolia*
AMTR	*Ambrosia trifida*
APCA	*Apocynum cannabinum*
ASINI	*Asclepias incarnata ssp. incarnata*
BAVE	*Barbarea vema*
BIFR	*Bidens frondosa*
BOCY	*Boehmeria cylindrica*
CAHI3	*Cardamine hirsuta*
CAIM	*Cardamine impatiens*
CEJA	*Centaurea jaceae*
CEGL2	*Cerastium glomeratum*
CIIN	*Cichorium intybus*
CILUC	*Circaea canadensis ssp. canadensis*
CIAR4	*Cirsium arvense*
CIDI	*Cirsium discolor*
COCO13	*Conoclinium coelestinum*
COCA5	*Conyza canadensis*
COVA2	*Coronilla varia*
DACA6	*Daucus carota*
DUIN	*Duchesnea indica*
ECLO	*Echinocystis lobata*
EPCI	*Epilobium ciliatum*
ERHI2	*Erechtites hieraciifolia*
ERST3	*Erigeron strigosus*
EUPE3	*Eupatorium perfoliatum*
EUST23	*Euphorbia serrulata*
EUGR5	*Euthamia graminifolia*
EUFI14	*Eutrochium fistulosum*
FASC	*Fallopia scandens*
GECA7	*Geum canadense Jacq.*
GLHE2	*Glechoma hederacea*
HELA	*Helianthus laetiflorus*
HEMA2	*Helianthus maximiliani*
HEHEH	*Heliopsis helianthoides var. helianthoides*
HYPU	*Hypericum punctatum*
IMCA	*Impatiens capensis*
IRPS2	*Iris pseudacorus*
LIVU2	*Linaria vulgaris*
LOIN	*Lobelia inflata*
LOSI	*Lobelia siphilitica*
LUAL2	*Ludwigia alternifolia*
LYEU	*Lycopus europeaus*
LYNU	*Lysimachia nummularia*
LYSA2	*Lythrum salicaria*
MAMO2	*Malva moschata*
MELU	*Medicago lupulina*

Forbs	
Symbol	**Latin Name**
MEOF	*Melilotus officinalis*
NAPS	*Narcissus pseudonarcissus*
OEBI	*Oenothera biennis*
OXST	*Oxalis stricta*
PELO10	*Persicaria longsetum*
POPE2	*Persicaria pensylvanica*
PEPU18	*Persicaria punctata*
PLLA	*Plantago lanceolata*
PLMA2	*Plantago major*
PLRU	*Plantago rugelii*
POAV	*Polygonum aviculare*
PRVU	*Prunella vulgaris*
RAFI	*Ranunculus ficaria var. bulbifera*
RUHI2	*Rudbeckia hirta*
RULA3	*Rudbeckia laciniata*
RUCR	*Rumex crispus*
RUSA	*Rumex salicifolius*
SIPE2	*Silphium perfoliatum*
SIAN3	*Sisyrinchium angustifolium*
SOCA3	*Solanum carolinense*
SOAL6	*Solidago altissima*
SOCA6	*Solidago canadensis*
SOGI	*Solidago gigantea*
SOLID	*Solidago sp*
SYLA6	*Symphyotrichum lanceolatum*
SYLA4	*Symphyotrichum lateriflorum*
SYNO2	*Symphyotrichum novae-angliae*
SYPU	*Symphyotrichum puniceum*
SYRA5	*Symphyotrichum racemosum*
SYOF	*Symphytum officinale*
URDI	*Urtica dioica*
VETH	*Verbascum thapsus*
VEUR	*Verbena urticifolia*
VEAL	*Verbesina alternifolia*
VENO	*Vernonia noveboracensis*
VEOF2	*Veronica officinale*
VEVI4	*Veronicastrum virginicum*
VISO	*Viola sororia*
XAST	*Xanthium strumarium*

Graminoids	
Symbol	**Latin Name**
AGGI2	*Agrostis gigantea*
ANGE	*Andropogon gerardii*
CAREX	*Carex sp*
CALU3	*Carex lupuliformis*
CAST5	*Carex stipata*
CYST	*Cyperus striqosus*
ECCH	*Echinochloa cruzgalli*
ELRE4	*Elymus repens*
ELVI3	*Elymus virginicus*
JUTE	*Juncus tenuis*
LEVI2	*Leersia virginica*
MIVI	*Microstegium vimineum*
MIVI	*Microstigium vineum*
MUSC	*Muhlenbergia schreberi*
PHAR3	*Phalaris arundinacea*
PHPR3	*Phleum pratense*
SCSCS	*Schizachyrium scoparium var. scoparium*
SCGE2	*Scirpus georgianus*
SEFA	*Setaria faberi Herrm.*
SEPU8	*Setaria pumila*
SONU2	*Sorghastrum nutans*
SONU2	*Sorghastrum nutans*
TRFL2	*Tridens flavus*

Sub-Shrubs / Shrubs	
Symbol	**Latin Name**
AMFR	*Amorpha fruticosa*
ROPA	*Rosa palustris*
TORA2	*Toxicodendron radicans*
ARVU	*Artemisia vulgaris*
GAOF	*Galega officinalis*
RUPH2	*Rubus pennsylvanicus*

Trees	
Symbol	**Latin Name**
ACSA2	*Acer saccharinum*
JUGLA	*Juglans sp.*
MALUS	*Malus sp.*
ULPA	*Ulmus parvifolia*

Vines	
Symbol	**Lantin Name**
AMBR7	*Ampelopsis brevipedunculata*
CASE13	*Calystegia sepium*
CEOR7	*Celastrus orbiculatus*
Fallopia	*Fallopia sp.*
HUJA	*Humulus japonicus*
LOJA	*Lonicera japonica*
VITIS	*Vitis vulpina*

Appendix D:
List of Species in the Soil Seed Bank

Upland Sheep Meadow
Acalypha rhomboidea
Ambrosia artemisiifolia
Ambrosia trifida
Cardamine hirsuta
Cardamine imaptiens
Cerastium glomeratum
Chenopodium album
Cirsium arvense
Conyza canadensis
Duchesnea indica
Epilobium ciliatum
Erechtites hieraciifolia
Eupatorium perfoliatum
Euphorbia nutans
Euthamia graminifolia
Geum canadense
Juncus sp
Lobelia sp.
Microstegium vimineum
Oenothera biennis
Oxalis stricta
Paspalum laeve
Paulownia tomentosa
Petunia
Plantago sp.
Potentilla norvegica
Rudbeckia hirta
Sagina japonica
Setaria sp.
Sisyrinchium angustifolium
Solanum carolinense
Solidago gigantea
Sorghastrum nutans
Trifolium
Verbascum thapsus
Verbena urticifolia L.
Veronica spp.
Viola sororia

Floodplain Entrance Meadow
Abutilon theophrasti
Acalypha rhomboidea
Ambrosia artemisiifolia
Anagallis arvensis
Artemisia vulgaris
Barbarea verna
Bidens frondosa
Buddleja davidii
Cardamine hirsuta
Cardamine imaptiens
Carex sp.
Cerastium glomeratum
Cirsium arvense
Conyza canadensis
Coronilla varia L.
Duchesnea indica
Epilobium parviflorum
Erechtites hieraciifolia
Erigeron sp
Eupatorium perfoliatum
Euphorbia nutans
Galega officinalis
Glechoma hederacea
Humulus japonicus
Juncus sp
Lepidium
Linaria vulgaris
Lobelia spp.
Lycopus sp
Lythrum salicaria
Mazus pumilus
Microstegium vimineum
Mollugo verticillata
Oenothera biennis
Oxalis stricta
Paspalum laeve
Paulownia tomentosa
Persicaria longsetum
Phalaris arundinacea
Plantago sp.
Polygonum aviculare
Portulaca oleracea
Potentilla norvegica
Prunella vulgaris
Ranunculus ficaria
Rumex spp.
Sagina japonica
Setaria sp.
Sisyrinchium angustifolium
Solanum nigrum
Solidago sp.
Sorghastrum nutans
Taraxacum officinale
Trifolium spp.
Urtica dioica
Verbena simplex
Verbena urticifolia L.
Verbesina alternifolia
Veronica spp.

Floodplain Grass Meadow
Ageratina altissima
Barbarea verna
Boehmeria cylindrica

Buddleja davidii
Cardamine hirsuta
Carex sp.
Cirsium arvense
Conyza canadensis
Epilobium ciliatum
Erechtites hieraciifolia
Eupatorium perfoliatum
Eylmus sp
Fallopia
Galega officinalis
Galinsoga quadriradiata
Juncus sp
Ludwigia palustris
Lycopus sp
Lythrum salicaria
Mazus pumilus
Microstegium vimineum
Oxalis stricta
Paulownia tomentosa
Persicaria
Persicaria longsetum
Phalaris arundinacea
Portulaca oleracea
Potentilla norvegica
Ranunculus sp
Rumex sp
Senecio vulgaris
Setaria sp.
Solanum carolinense
Solidago gigantea
Symphytum officinale
Taraxacum officinale
Trifolium
Urtica dioica
Verbena urticifolia
Veronica peregrina ssp. peregrina

TITLE: **THE PHILLY BEES' STAKE IN POLLINATION: THE BEES OF PHILADELPHIA**

AUTHOR: **Stephanie Wilson**
The John J. Willaman & Martha Haas Valentine Endowed Plant Protection Intern

DATE: **May 2013**

ABSTRACT:

This study is part of a larger United States Geological Survey of the bees in the United States as part of a monitoring program of the flora and fauna of North America. While bees have been studied across Pennsylvania, in New York City and Baltimore, this is the first documented survey of the bees of Philadelphia. I sampled bees by netting once in July, August, and September. A total of 280 bees, representing 58 species were captured. This is the first record of several bee species for Pennsylvania, including the recently introduced *Hylaeus hyalinatus* Smith and *Coelioxys coturnix* Perez. I also document the presence of *Bombus pensylvanicus* Perez, a bumble bee that may be in decline. This study can be used to guide monitoring and conservation efforts.

The Philly Bees' Stake in Pollination: The Bees of Philadelphia

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INTRODUCTION

Wild bees are necessary and sufficient for the pollination of crops and the perpetuation of gardens. Garibaldi *et al.* (2013) suggested that wild insect pollination resulted in twice as much fruit set as honey bee pollination in crop fields across all continents, excluding Antarctica. Winfree et al. (2008) reported that wild bees sufficiently pollinated the watermelon crop on the majority of farms sampled in Pennsylvania and New Jersey.

The majority (95%) of bee species that have been documented for eastern North America have been captured at least once since 1990. This suggests that bee richness is not in decline in the eastern United States (Colla et al., 2012). However, populations of at least two species of bumble bees, *Bombus affinis* Cresson and *Bombus pensylvanicus* Perez, may be in decline (Colla et al., 2012). The United States Geological Survey is now conducting surveys across the country to analyze that status of bee populations in the United States.

Bees occur in high abundance is urban settings, but no papers on bee populations outside of New York, NY and Baltimore, MD have been published for cities in the Northeastern United States (Droege & Shapiro 2011 and Matteson et al. 2008). Specifically, there are no published studies of the wild bees of Philadelphia, despite the city's size, location mid-way between New York and Baltimore, and its status as an active port located on the East Coast Fall Line.

According to Cane (2005) in *Bees' Needs Challenged by Urbanization*, urban bee populations are different from rural and wild bee populations because of several characteristics. First, they are smaller because there is less habitat. Second, there are fewer ground nesting bees because of the prevalence of pavement and turf. Third, since there are less floral resources over all, there are fewer oligolectic bee species, defined as bees that collect from three families of plants or less (Wilmer, 2011). Fourth, there are fewer cleptoparasitic bees because of smaller populations of bees. Cleptoparastic bees represent the apex of bee communities and are only present where there are large enough populations of host bees to support parasitism (Sheffield, Pindar, Packer, & Kevan, 2013). Fifth, in large port cities, like Philadelphia, there are more likely to be exotic species, introduced from shipments.

The purpose of this study is to provide information on the richness of bees within the city and to create a record of bees in Philadelphia for future monitoring.

MATERIALS AND METHODS

I net collected once in 10 community gardens and multiple times in the Morris Arboretum in Philadelphia County from late June (6/25/2012) to October (10/16/2012) (Table 1). The Morris Arboretum is ecologically different from the gardens, but is still within the city boundary. This is a time independent survey since my purpose was only to document what bees are present. If I could identify the bee in the field and its presence was documented for the area, I did not capture it (eg. *Xylocopa virginica* Linnaeus and *Bombus impatiens* Cresson). I used a BioQuip Products 38.1 -centimeter (15-inch) diameter model net. The bees were suffocated in ethyl acetate kill jars or frozen.

I pinned and labeled the bees and then identified them using the Discover Life Random Access Key (The Polistes Foundation, 2013). S. Droege confirmed my identifications. I used literature searches to determine whether the presence of each bee had been documented in Pennsylvania and Philadelphia (Donovall & vanEngelsdorp 2010; Tonietto & Ashcer, 2002; Vickruck, and Rehan, Sheffield, & Richards 2011) and whether or not the bee fell within the following categories: native, cleptoparasitic, oligolectic, and ground nesting (Table 2).

RESULTS

A total of 280 bee specimens (including two unidentified male *Lasioglossum*) were netted in the summer of 2012 in Philadelphia County, representing 58 species. Five species (9%) had not been documented for Pennsylvania and 18 species (31%) had not been documented in Philadelphia. Five species (9%) were introduced taxa. Seven (12%) were cleptoparasites. Fourteen (24%) were oligolectic species and thirty-four (59%) were ground nesting (Table 2).

DISCCUSSION

The majority of bees that had not been documented in Pennsylvania were in the genus *Lasioglossum* (all but one). This result is not surprising since researchers are still constructing this group's taxonomy. For example, the species *Lasioglossum gotham* Gibbs has not been recorded in Pennsylvania, but the classification of the species itself is recent (2011) (The Polistes Foundation, 2013).

Ceratina mikmaqi Rehan & Sheffield, which I netted at Benjamin Rush State Park, is an uncommon oligolectic species (The Polistes Foundation, 2013). I netted the uncommon bee *Lasioglossum taylorae* Gibbs as it was foraging on *Datura stramonium* L. at the Morris Arboretum. No floral hosts have been recorded for this species until now (The Polistes Foundation, 2013). Other oligolectic species include *Melissodes* sp. that were foraging on *Helianthus* in many of the community gardens, as well as males of the squash bee, *Peponapis pruinosa* Say, that were collected in squash flowers in Warrington Community Garden in West Philadelphia.

The exotic bee species that I captured included *Anthidium manicatum* L. and *Anthidium oblongatum* Illiger, both of which have spread from Europe and whose presence in North America is well known (The Polistes Foundation, 2002). I collected *Megachile apicalis* Spinosa from *Cirsium* in Pennypack State Park. This European bee has been documented in New York and Baltimore but not in Philadelphia (The Polistes Foundation, 2013). *Hylaeus hyalinatus* Smith is a recently introduced species from Europe. This is the first record of it in Philadelphia.

I netted the cleptoparasitic bee, *Coelioxys coturnix* Perez in Southwark Community Garden in South Philadelphia. This bee was recently introduced from Europe (The Polistes Foundation, 2013). Interestingly enough, its host species, *Megachile minutissima* Radoszkowski has not been documented as present in North America. (Figure 1). It is believed to be parasitic on *Megachile rotundata* Fabricius, an introduced bee species from Europe (Droege & Shapiro, 2011).

I netted a single *Bombus pensylvanicus* Perez at Maple Acres Farm (40° 7' 6", 75° 16' 23"). This farm is not in Philadelphia County, but this specimen is worth noting because *Bombus pensylvanicus* populations may be in decline (Colla et al., 2012).

SIGNIFICANCE AND BROADER IMPACT

This study reports the presence of several bees that were undocumented for this area and provides information about the diversity of bee species in Philadelphia. The presence of the *Coelioxys coturnix* suggests that bee populations within the city are at least large enough to support cleptoparasitic bees, though it warrants further research and documentation of its specific hosts here in North America. The single capture of *Bombus pensylvanicus* indicates that this bumble bee is still present in the area, but not in abundance.

Using this research, I have presented information about native bees at several events in the Philadelphia community, including at the Philadelphia Honey Festival, a volunteer workshop at the Morris Arboretum, and an event at the Franklin Institute. I will deposit the specimens at the Academy of Natural Sciences of Drexel University in Philadelphia, PA for future reference.

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APPENDIX

Table 1. Gardens in Philadelphia where I collected specimens.

Garden	Address	Location	Latitude	Longitude
Bartram's Garden	54th Street and Lindbergh Boulevard	West	39° 55' 57"	75° 12' 44"
Bel Arbor Community Garden	1018 Kimball Street	South	39° 56' 16"	75° 9' 38
Benjamin Rush State Park	Roosevelt Blvd & Southhampton Rd.	North East	40° 7' 10"	74° 58' 36"
The Morris Arboretum	100 Northwestern Avenue	North West	40° 5' 30"	75° 13' 29"
Pennypack Park	7979 State Rd.	North East	40° 3' 55"	75° 2' 20"
South Street Community Garden	837 South St.	South	39° 56' 34"	75° 9' 23"
Southwark / Queen Village Community Garden	311 Christian St.	South	39° 56' 13"	75° 8' 57"
Warrington Community Garden	4731 Warrington Ave.	West	39° 56' 53	75° 13' 4"
St. Bernard Community Garden	1010 S. St. Bernard St.	West	39° 56' 39	75° 13' 5"
Kingsessing and 47th	1128 South 47th Street	West	39° 56' 43"	75° 12' 46

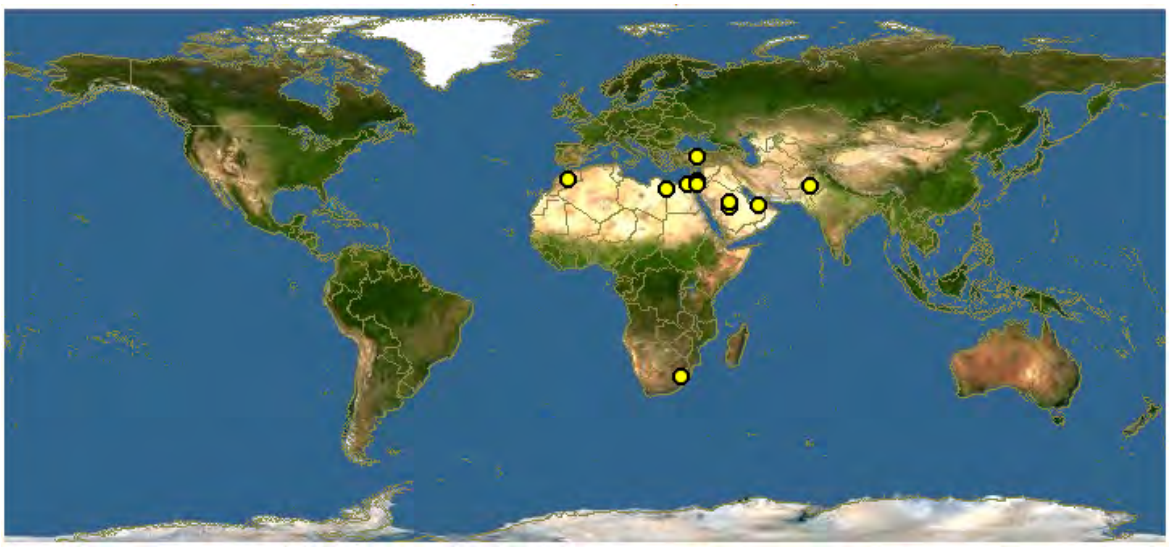
Table 2. Specimen data. 1 and 0 represent true and false, respectively, for each characteristic.

Genus species	Count	Richness	Documented PA?	Documented Phila?	Native?	Cleptoparasitic?	Oligolectic?	Gr nes
Agapostemon	**5**							
sericeus	1	1	1	1	1	0	0	
texanus	1	1	1	1	1	0	0	
virescens	3	1	1	1	1	0	0	
Anthidium	**7**							
manicatum	4	1	1	1	0	0	0	
oblongatum	3	1	1	1	0	0	0	
Augochlora	**8**							
pura	8	1	1	1	1	0	0	
Augochlorella	**4**							
aurata	4	1	1	1	1	0	0	
Augochloropsis	**3**							
metallica	3	1	1	1	1	0	0	
Bombus	**42**							
auricormis	1	1	1	1	1	0	0	
bimaculatus	7	1	1	1	1	0	0	
fervidus	8	1	1	1	1	0	0	
griseocollis	13	1	1	1	1	0	0	
impatiens	10	1	1	1	1	0	0	
pennsylvanicus	1	1	1	1	1	0	0	
Ceratina	**20**							
calcarata	14	1	1	1	1	0	0	
dupla	4	1	1	1	1	0	0	
mikmagi	1	1	1	0	1	0	1	
strenua	1	1	1	1	1	0	0	
Coelioxys	**3**							
coturnix	2	1	0	0	0	1	0	
sayi (octodentata)	1	1	1	1	1	1	0	
Epeolus	**1**							
bifasciatus	1	1	1	1	1	1	1	
Halictus	**60**							
confusus	5	1	1	1	1	0	0	
ligatus	44	1	1	1	1	0	0	
parallelus	1	1	1	1	1	0	0	
rubicundus	10	1	1	1	1	0	0	
Holocopasites	**1**							
calliopsidis	1	1	1	1	1	1	1	
Hylaeus	**10**							

hyalinatus	3	1	1	0	0	0	1
mesillae	2	1	1	0	1	0	0
modestus	5	1	1	1	1	0	0
Lasioglossum	**39**						
bruneri	2	1	1	1	1	0	0
callidum	2	1	0	0	1	0	0
coriaceum	2	1	1	0	1	0	0
gotham	1	1	0	0	1	0	0
illnoense	2	1	1	0	1	0	0
imitatum	17	1	1	1	1	0	0
pilosum	2	1	1	1	1	0	0
quebecense	1	1	1	0	1	0	0
taylorae	5	1	0	0	1	0	1
trigeminum	3	1	0	0	1	0	1
versatum	2	1	1	0	1	0	0
Megachile	**28**						
apicalis	1	1	1	0	0	0	1
brevis	9	1	1	1	1	0	0
campanulae	1	1	1	1	1	0	0
centuncularis	4	1	1	1	1	0	0
exilis	1	1	1	1	1	0	0
mendica	4	1	1	1	1	0	0
pugnata	3	1	1	0	1	0	0
relativa	1	1	1	0	1	0	0
rotundata	4	1	1	1	1	0	0
Mellisodes	**39**						
agilis/trinodis	24	1	1	1	1	0	1
bimaculata	4	1	1	1	1	0	0
desponsa	11	1	1	1	1	0	1
Peponapis	**4**						
pruinosa	4	1	1	1	1	0	1
Pseudopanargus	**1**						
compositorum	1	1	1	0	1	0	1
Triepeolus	**4**						
helianthi	1	1	1	0	1	1	1
remigatus	2	1	1	1	1	1	1
simplex	1	1	1	0	1	1	1
Xylocopa	**1**						
virginica	1	1	1	1	1	0	0
Grand Total	**280**	**58**	**53**	**40**	**53**	**7**	**14**

Figure 1. Comparison of distribution of *Coelioxys coturnix* and *Megachile minutissima*.

Distribution of *Coelioxys coturnix*.



Distribution of *Megachile minutissim*