Morris Arboretum of the University of Pennsylvania

Official arboretum of the Commonwealth of Pennsylvania

FINAL INDEPENDENT PROJECT REPORTS

Completed in Partial Fulfillment of the

Requirements of the 2010-2011

Morris Arboretum Internship Program

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TITLE: MORRIS ARBORETUM GREEN ROOF EVOLUTION TRACKING

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DATE: June 2011

ABSTRACT:

Morris Arboretum's intensive and extensive green roofs are one of the Horticulture Center's many green features. The planting material used on these roofs is experimental in this region. Because there are only a few green roofs in the Philadelphia area, little research has been done on what plants do well in these specific conditions. Green roofs have many limiting factors, which include limited growing space, extreme light and heat intensity, susceptibility to high winds, and moisture stress. Morris Arboretum's green roof was designed to be functional as well as aesthetically pleasing. The intensive green roof uses a variety of grasses, shrubs, annuals, and perennials in its design.

The purpose of this study is to determine what plants from the original installation have done well under the harsh conditions of the green roof, which annuals were successful in reseeding, and how larger shrubs have filled in the space. This study also provides information on the seasonal interest of the roof—including spring emergence, bloom time, seed formation, and fall color. This information will be useful in future designs for green roofs in this area.

Morris Arboretum Green Roof Evolution Tracking

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ACKNOWLEDGEMENTS

I would like to thank Tony Aiello, Director of Horticulture and Louise Clarke, Horticulture Section Leader for Bloomfield Farm, for their support and guidance throughout this project, Carolyn Catani, Horticulture Intern, for her help in CAD, and Paul Meyer, the F. Otto Haas Director of the Morris Arboretum for his help in documenting the green roofs by providing photos.

INTRODUCTION

With the recent dedication of the Horticulture Center, The Morris Arboretum is taking the lead in sustainable and modern design. This building is one of few that were built to meet LEED platinum standards—the highest level in sustainable building standards. With these forward-looking goals of sustainability the Horticulture Center includes features such as geothermal heating and cooling, green lighting, and a rain garden complete with rain collecting cisterns.

In addition to these features, green roofs lay atop both the four-bay and six-bay garages. The four-bay garage is planted with sedum mats from Sempergreen and the six-bay garage is planted according to a design by 2009-2010 Natural Lands Intern, Sarah Presogna.

The installation of this green roof meets with the Morris Arboretum's mission of "promot[ing] an understanding of the relationship between plants, people and place," by connecting working space with aesthetic quality via environmentally sound concepts and natural design. It also "integrate[s] science [and] art" by incorporating a carefully designed, yet experimental, planting plan on these newly established buildings. In addition to this, the green roofs act as a learning opportunity, and make for many "teachable moments" for newcomers to the Horticulture Center.

The purpose of my project was to track the evolution of these two roofs over the course of this year. I assessed plant health, as well as seasonal interest. This included observing bloom time, dormancy in the fall, and reemergence in the spring. I also tracked plant distribution to assess reseeding and vegetative growth. Grid markers were placed on the roof to help me with this effort. This data is important to reap the maximum benefits from the roofs.

It is a common misconception that green roofs need little to no maintenance, because the roof was designed with harsh conditions in mind. However, some plants that we trialed did not do well despite their hardiness. One must realize that plants on a green roof must withstand moisture stress, elevated temperatures, high light intensities, and high wind speeds[1]. This first year gave us the opportunity to observe the different plants, and how readily they established themselves. This data helps us in determining which plants need little to no care from its installation throughout its life.

In addition to the initial plant layout, I also did several trials on the roofs which include planting spring and fall flowering bulbs as well as taking a look at different methods of Sedum propagation. I have developed a simple plant log to document changes in the plants themselves as well as log any actions we took on the roof.

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[1] Oberndorfer, Erica, Jeremy Lundholm, et. al. "Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services." BioScience. November 2007. 57: 10. Pp 825.

As the only changing entity of the actual buildings themselves, it is important to keep records to develop a maintenance routine for the green roof. This data will also provide valuable information on future green roofing projects in this area.

GREEN ROOF BASICS

The simplest definition of a green roof is: a roof that has purposefully installed plant material as a permanent feature of the building itself. They differ from non-permanent roof gardens because, in green roofs, the plant growing medium is incorporated into the building instead of in pots or planters.

Although green roofs are a relatively new trend in North America, they are quite common in Europe. Early European green roof research in the 70s and 80s led to their popularity. Today, Germany's green roofs increase by about 145 million square feet per year[2]!

There are many reasons for their popularity. One reason to install a green roof is for their aesthetic value. Property values for taller, surrounding buildings also increase because of they serve as a pleasing break from the "concrete jungle." Additionally, there are practical reasons for installing green roofs. This includes: reducing and filtering storm water runoff, reducing dust and pollution surrounding the building, cooling and humidifying the air, and releasing additional oxygen[3].

These benefits can have important environmental implications. Urban development often correlates with the increase of impervious surfaces. This, in turn, causes increased storm water runoff that diverts into streams and other bodies of water when it rains. These storm water systems often cannot handle the increased runoff, which then result in flooding and damage. Green roofs provide an effective storm water management system for the areas they cover by absorbing the rain that falls on them. A green roof does this by absorbing rain water in its substrate. This is especially effective for smaller rain events. For higher-intensity storms, green roofs help mitigate runoff by spreading out runoff over a longer period of time, allowing watersheds more time to divert this storm water[4].

Adding vegetation to a building is also beneficial because it can reduce the building's energy consumption. [5] A green roof can mitigate extreme temperatures, minimizing heating and cooling costs. Research suggests that the energy is conserved by the reduction of heat flow into buildings in warmer temperatures, and the reduction of heat loss through the roof in cooler temperatures[6].

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[2] Snodgrass, Edmund C. and McIntyre, Linda. 2010. The Green Roof Manual: A Professional Guide to Design, Installation, and Maintenance. Timber Press. Portland, OR. Pp. 38

[3] Clarke, Louise. "Green Roofs from the Ground Up." Power Point Presentation. Morris Arboretum. Philadelphia, PA. 22 Sept 2010.

[4] Dunnett, Nigel and Kingsbury, Noel. 2008. Planting Green Roofs and Living Walls.Timber Press. Portland, OR. Pp. Pp. 57

[5] Ibid Oberndorfer et. al. Pp 823.

[6] Ibid Sonodgrass et. al.

Green roofs are usually categorized as being either intensive or extensive. An extensive green roof has a shallower profile, with only about six inches of growing medium or less. These roofs are usually planted with sedums, grasses, or other low maintenance, hardy plants. Intensive roofs, however, have deeper profiles and range from six to eight inches in depth. These roofs are usually designed to be more of a conventional garden, where plants are cared for individually. Also, because the roof has a deeper profile, it is able to support more plant types including: grasses, shrubs, annuals, and perennials[7].

Intensive roofs allow building owners to get creative with the design and plant materials that they can use in this space. However, this flexibility often comes with the responsibility of more intensive plant care. Additionally, the aesthetic expectations for intensive roofs highly increase with more complicated plantings[8].

METHODS

The plants observed in this study are located on the Morris Arboretum's intensive green roof above the Horticulture Center's six-bay garage. The site measured 144' x 24' with a substrate that is eight inches deep.

Throughout this project, I tracked each species on the Morris Arboretum's intensive green roof. Records were taken once a week via photos and a written log. Observations I made include: spring emergence, bloom time, seed formation, and fall color. I also noted if any plants were diseased, struggling, or dead. I documented any actions we took on the roof including irrigation, weeding, and other types of maintenance.

The seasonal interest of the roof was recorded into an Excel spreadsheet, using colors to represent different lifecycle changes in each species. This gives a visual representation of peak seasonal interest times on the roof. This information will be analyzed to determine when there is little seasonal interest on the roof, and what we can do or add to make the roof an aesthetic feature of the Horticulture Center during all seasons.

This data will provide valuable information on future green roofing projects in this area.

[7] Ibid Dunnett Pp. 4.
[8] Ibid Orbendorfer et. al. Pp. 824

RESULTS

The attached Excel sheet as a visual representation of seasonal interest documents when plants have leaves and their bloom time. I also have photo documentation of the roof throughout my time here, which will act as a resource for future use.

Plants no longer present on the Roof:
Agave Americana var. protoamericana 'Silver Surfer'
Agave parryi var. truncata
Agave sp. 'Mr. Ripple'

HORTICULTURE CENTER GREENROOF BLOOM AND FOLIAGE LOG 2010

Horticulture Center Greenroof Bloom and Foliage Log 2010

Month	August		September				October				November					December											
Week	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52								
Key		Few Blooms				Moderately Blooming					Full Bloom				No flowers												
																	X	Not present or unobservable									
		Leafing Out			Fully Leafed			Moderate Fall Color				Full Fall Color			No leaves		$	Seeds present									
Plants																											
Achillea millefolium									$	$	$	$	$	$	$	$	$	$	$								
Achillea tomentosa "Aurea"									$	$	$	$	$	$	$	$	$	$	$								
Achillea x 'Fireland'									$	$	$	$	$	$	$	$	$	$	$								
Achillea x 'Terra Cotta'									$	$	$	$	$	$	$	$	$	$	$								
Aesclepius tuberosa					$	$	$	$	$																		
Agave Americana var. protoamericana 'Silver Surfer'																											
Agave parryi var. truncata																											
Agave sp. 'Mr. Ripple'																											
Allium cernuum																											
Allium schoenoprasum																											
Allium thunbergii 'Ozawa'																											
Andropogon gerardii																											
Antennaria dioica	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
Aquilegia canadensis 'Little Lanterns'	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
Aquuilegia canadensis	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X								
Armeria maritima 'Rubifolia'																											
Artemesia ludoviciana 'Silver Frost'																											
Artemesia x 'Powis Castle'																											
Calamagrostis 'Karl Foerster'																											

Horticulture Center Greenroof Bloom and Foliage Log 2010

Month	August		September				October				November					December								
Week	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52					
Key		Few Blooms				Moderately Blooming					Full Bloom				No flowers			X	Not present or unobservable					
		Leafing Out			Fully Leafed			Moderate Fall Color				Full Fall Color			No leaves									
Calluna vulgaris 'Firefly'	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Carex eburnea																								
Carex flacca																								
Cerastium tomentosum 'Yoyo'																								
Crocus chrysanthus 'Blue Bird'	X	X	X	X	X	X	X	planted	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	planted	X	X	X	X	X	X	X	X	X	X	X					
Crocus medius	X	X	X	X	X	X	X	planted	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	planted	X	X	X	X	X	X	X	X	X	X	X					
Crocus ochroleucus	X	X	X	X	X	X	X	planted	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	planted	X	X	X	X	X	X	X	X	X	X	X					
Delosperma cooperi										S	S	S	S	S	S	S	S	S	S					
Delosperma dyeri										S	S	S	S	S	S	S	S	S	S					
Delosperma nubigenum 'Basutoland'										S	S	S	S	S	S	S	S	S	S					
Dianthus deltoides 'Arctic Fire'																								
Dianthus gratianopolitanus																								
Gypsophila repens 'Alba'																								
Iberis sempervirens 'Little Gem'																								
Iberis sempervirens 'Snowflake'																								
Juniperus conferta 'Silver Mist'	Replaced some with smaller plants											Some dead												
Juniperus horizontalis 'Bar Harbor'																								
Juniperus horizontalis 'Wiltoni'																								
Lavandula x intermedia 'Seal'																								
Monarda fistulosa 'Petite Wonder'	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Muscari armeniacum 'Christmas Pearl'	not yet planted							planted	X	X	X	X	X	X	X	X	X	X	X					
	not yet planted							planted	X	X	X	X	X	X	X	X	X	X	X					

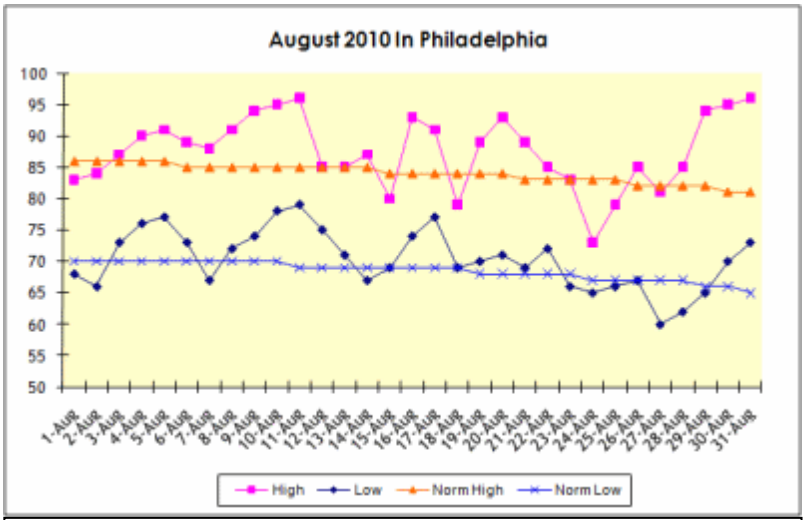
Horticulture Center Greenroof Bloom and Foliage Log 2010

Month	August		September				October				November					December								
Week	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52					
Key		Few Blooms				Moderately Blooming					Full Bloom				No flowers			X	Not present or unobservable					
		Leafing Out			Fully Leafed			Moderate Fall Color				Full Fall Color			No leaves									
Nepta faassenii 'walker's low'																								
Papaver alpinum	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Pennisetum 'Foxtrot'				$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$					
Pennisetum 'Little Bunny'					$	$	$	$	$	$	$	$	$	$	$	$	$	$	$					
Penstemon pinifolius																								
Penstemon pinifolius 'Magdalena Sunshine'																								
Perovskia atriplicifolia 'Little Spire'																								
Phlox subulata 'Emerald Blue'																								
Phlox subulata 'Scarlet Flame'																								
Rhus aromatica 'Gro-Low'																								
Rosmarinus officinalis 'Arp'																								
Schizachyrium scoparium																								
Schizachyrium scoparium 'Prarie Blues'																								
Sedum acre 'Aureum'																								
Sedum album																								
Sedum cauticolum 'Lidakense'																								
Sedum floriferum 'Weinhenstephaner Gold'																								
Sedum 'Silver Stone'																								
Sedum spurium 'Coccineum'																								
Sedum spurium 'Voodoo'																								
Sedum spurium 'White Form'																								

Horticulture Center Greenroof Bloom and Foliage Log 2010

Month	August		September				October				November					December								
Week	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52					
Key		Few Blooms				Moderately Blooming					Full Bloom				No flowers			X	Not present or unobservable					
		Leafing Out			Fully Leafed			Moderate Fall Color				Full Fall Color			No leaves									
Sempervivum 'Imperial'	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Sempervivum 'Kalinda'	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Sempervivum 'Fame Monstrose'	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Sempervivum hausmanii	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Sempervivum 'Imperial	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Sempervivum 'Kalinda'	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
Solidago caesia																								
Sorghastum mutans																								
Sporobulus heterolepis																								
Talinum teretifolius																								
Thymus serpyllum 'Magic Carpet'																								
Tradescantia ohiensis					S	S	S	S	S															
Triteleia 'Rudy'	not yet planted							planted	X	X	X	X	X	X	X	X	X	X	X					
									X	X	X	X	X	X	X	X	X	X	X					
Tulipia bakeri 'Lilac Wonder'	not yet planted							planted	X	X	X	X	X	X	X	X	X	X	X					
									X	X	X	X	X	X	X	X	X	X	X					
Tulipia batalinii 'Bronze charm'	not yet planted							planted	X	X	X	X	X	X	X	X	X	X	X					
									X	X	X	X	X	X	X	X	X	X	X					
Tulipia humilis 'Alba Coerulea Oculata'	not yet planted							planted	X	X	X	X	X	X	X	X	X	X	X					
Yucca aloifolia 'Marginata'																								
Yucca filamentosa 'Color Guard'																								
Yucca gloriosa 'Variegata'																								

DISCUSSION



Credit: Phillyweather.net

It is a common misconception that green roofs need little to no maintenance. This may be true in an accommodating environment, where rain and mild weather conditions exist. However, the installation of the green roofs in March 2010 was followed by a particularly hot and dry summer. "The warmest summer on record was [the result of the] warmest June, second warmest July, and 8th warmest August since 1872 in Philadelphia.[9]" In conjunction with the "dry spell that has lingered over the region since the start of April,"[10], the newly installed green roof plants struggled to adapt to their new environment. Without supplemental water, many plants suffered drought stress, which may have inhibited some from successful establishment.

A recommendation to counter this limitation is to install an irrigation system. This is especially important for green roofs in their infancy. We did try to add some supplemental water during July and August 2010 via oscillating sprinklers. However, we experienced some problems. One of these was getting full irrigation coverage on the roof. Because the roof was so high, winds often diverted the direction of the water, causing both wet and dry spots. Additionally, getting sufficient water pressure to power the sprinklers was often a problem. This was especially true when nearby water sources were being utilized simultaneously. This inconsistent and spotty watering may have given some plants an advantage that others did not have.

In addition to being spotty and inconsistent, watering using this method was also time consuming. Because we only were able to get one hose line up there, we needed to move it approximately every hour throughout the day to cover the whole roof.

New methods of irrigation will be tested this upcoming season.

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[9] Phillyweather.net:The Delaware Valley's Weather Center. "August 2010 Cements Hottest Summer on Record." http://philadelphiaweather.blogspot.com/2010/09/august-2010-cements-hottest-summer-on.html . Accessed: March 21, 2011.

[10] Ibid Phillyweather.net

CONCLUSION

I have included a maintenance plan and instruction sheet for the green roof. I have included recommendations for plantings that will add more interest during seasonal lulls and create a list of plants that do well on our roof. This list will provide other green roof designers in our area a planting recommendation resource.

MAINTENANCE PLAN

January—Roof inaccessible because of snow
February—Roof inaccessible because of snow
March
- Cut back any dead wood—this applies especially to Artemesia, Nepeta, Rosmarinus, Lavendula, and Solidago
- Remove fleshy plant parts that have been freezer burned
- Cut back grasses to base

April
- Weed as necessary, look out especially for dandelions
- Continue to cut back any dead wood
- Cut back Perovskia when buds are swollen
- Check for any dead plants—remove
- Reorder and replace dead plants

May:
- Weed as necessary

June:
- Water as necessary
- Weed as necessary, look out for Prostrate Spurge (*Euphorbia maculata*)

July
- Water as necessary
- Weed as necessary

August
- Water as necessary
- Weed as necessary

September:
- Order spring-flowering bulbs
- Propagate Sedum by taking cuttings and placing it on open spots

October:
- Plant bulbs for next spring
- Continue to propagate sedum

November:
- Cut back plants damaged from first frost or that have dried out from earlier in the season

December:
- Continue to cut back frost damaged or dried out plants (This task may be saved for the following spring)

FUTURE RECOMMENDATIONS

- Use large swaths of flowering plants for a more striking effect—*Ibiris* was delightful to look at on the roof, but was had impact when viewing from the ground because they were too spread apart. Planting them more densely and in larger quantities would have had a bigger impact. Other plants we could plant in larger quantities include: Dianthus, Opuntia, Phlox and Solidago.

- Plant more spring-flowering bulbs in larger numbers—This year we trialed species tulips. These did well and are some of the earliest flowering plants on the roof. Their planting should be continued in densely, and in larger quantities. *Crocus chrysanthus* 'Blue Bird' was the first to flower.

- Have a more permanent irrigation structure—having hoses on the green roof is difficult and dangerous for both the plants and operator. Having a more permanent irrigation line up there would save time as well as keep the plants from getting run over from the hose.

- Use plants that flower earlier in the season. Maybe early flowering bulbs like Siberian Squill or Winter Aconite.

SUGGESTED PLANT LIST

Missouri Evening Primrose—*Oenothera macrocarpa*

Blush Sage—*Salvia* 'Raspberry Delight'

Mojave Sage—*Salvia pachyphylla*

Blanket Flower—*Gaillardia* 'Kobold'

Blue Star—*Amsonia hubrichtii*

Lamb's Ear—*Stachys byzantine*

Roman chamomile—*Chamaemelum nobile*

Moss Rose—*Portulaca grandiflora*

REFERENCES

Clarke, Louise. "Green Roofs from the Ground Up." Power Point Presentation. Morris Arboretum. Philadelphia, PA. 22 Sept 2010.

Oberndorfer, Erica, Jeremy Lundholm, et. al. "Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services." BioScience. November 2007. 57 :10. Pp. 823-833

Phillyweather.net:The Delaware Valley's Weather Center. "August 2010 Cements Hottest Summer on Record." http://philadelphiaweather.blogspot.com/2010/09/august-2010-cements-hottest-summer-on.html . Accessed: March 21, 2011.

Snodgrass, Edmund C. and McIntyre, Linda. 2010. The Green Roof Manual: A Professional Guide to Design, Installation, and Maintenance. Timber Press. Portland, OR.

TITLE: MORRIS ARBORETUM EMERALD ASH BORER PLAN: Planning for the Imminent Arrival of Emerald Ash Borer (EAB) (*Agrilus planipennis* Fairmaire) and its effect on *Fraxinus* spp;

To be Adapted and Modified for Future Impact of *Geosmithia morbida*, Causal Agent of 'Thousand Cankers Disease' (TCD) on *Juglans* spp., Vectored by *Pityophthorus juglandis* (walnut twig beetle)

AUTHOR: Rebecca L. Bakker
The Martha S. Miller Endowed Urban Forestry Intern

DATE: May 2011

ABSTRACT:

Are the splendid botanical edifices in arboreta collections archaic? Millennia of poor land management, increased global trade, and climate change, have combined to create radical changes in plant communities and forest ecosystems. As a result, not just individual plants but whole genera are being eradicated. As global trade mounts and more goods are plied overseas, both intentional and accidental cargos have been altering ecosystems around the world. According to a study by Maher in Agricultural and Resource Economics Review (2006), the yearly economic impact of invasive species in the U.S. is estimated at $133.6 billion. One such migrant, the emerald ash borer (EAB) *(Agrilus planipennis* Fairemaire*)*, was identified in 2002 and thought to have arrived via shipping material from China to the U.S.'s upper Midwest. The consequence has been 100% mortality of all native North American ash exposed to EAB. Since its discovery, the insect has made its way relentlessly east and now approaches eastern Pennsylvania and Morris Arboretum, in particular.

Planning for the future of *Fraxinus* spp. was a luxury not found in the upper Midwest ten years ago, when clouds of unidentified green beetles were noticed feeding on ash trees. As the arrival of this destructive insect becomes imminent at the Morris Arboretum, a general and specific readiness plan must be put into place to reduce risk, minimize impact, and respond effectively to this invasion. This policy provides guidelines and methods for tree and pest survey, as well as education, control, and eradication strategies to support management efforts. Best management practices, limited as they are, and still evolving. As more and better information becomes available these practices must be put into place and updated regularly. Restoration of ecosystems, diversification, seed storage, and hybridization for resistant species are critical as the effects of globalization and climate change become more entrenched.

Morris Arboretum Emerald Ash Borer Plan

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INTRODUCTION

In the early years of human civilization, the inscrutability and mystery of the cosmos was likened to the tree, becoming its symbol. Perhaps those high cirrus clouds were actually branches (Appendix A, Fig.1). The ancient Norse civilization had stories about this Cosmic or World Tree, with its top in the heavens, its roots deep in the earth and underworld, calling it *Yggdrasil* (Internet Sacred Texts Archive). A tree canopy, living high, as in the realm of the gods must also, therefore, be divine. The tree "with its seed, its roots, its trunk, its resting perches, its knitting knots, its pith, its main branch, its leaves, its flowers and their sweet smell, it's refreshing shade, its immortal sap, and the spot where it grows, all brought into close and exquisite analogy with man and his universe" (http://www.sacred-texts.com/earth/boe/boe16.htm).

Seen as a mediating link between earth and the heavens, the ash (*Fraxinus excelsior*), which grows throughout Europe, became sacred in myth, folklore, and religion. The *Edda*, a collection of Nordic poetry relates how Odin (or Wodan) the High God of the Vikings, made the first man from a block of ash wood. The first woman was created from alder (Boom and Kleijn). Interpreted in many ways by many civilizations, trees were not considered themselves divine but dwelling places of the gods.

The world we live in in the 21st century is very different. Oceans have been crossed and land barriers scaled. Nor did humans travel alone. They have always brought with them their "crop plants, domesticated animals, pets, pathogens, and parasites" (Nentwig 2007). In addition, millennia of poor land management, whether from ignorance or outright disregard for ecosystem needs, has led to degradation of natural environments and contributed to climate change. These factors, combined with increased global trade, mean that the thirty new invasive insects discovered annually in the U.S. find a viable and proliferative new home with untold quantities of vulnerable vegetation and few, if any, natural predators (Nentwig 2007).

As global trade has mounted, more goods come from overseas, sometimes bringing with them accidental cargo of destructive bugs and plants, some even to public gardens. An estimated 500 million plants are imported to the U.S. each year. Shipments through one plant inspection station doubled to 52,540 between 2004 and 2006, according to the U.S. Department of Agriculture. In a study found in Agricultural and Resource Economics Review in 2006, the entire yearly economic impact of invasive species in the U.S. is estimated at $133.6 billion. That number includes the cost of control and prevention such as pesticides, inspection programs at ports, and damage to crops" (Maher 2008). There have been no significant revisions to import laws since 1918. New regulations were proposed in 2009 to ban imports of certain plants but USDA says inspection is approaching or may have reached the limits of efficiency. According to Richard Schulhof of the Arnold Arboretum,

> "A 2002 National Academy of Sciences study determined that the U.S. Department of Agriculture (USDA) inspects roughly 2 per cent of cargo shipments yet intercepts over 53,000 arthropods, pathogens and plants annually. Although few

> introduced organisms successfully establish, it is conservatively predicted the one hundred fifteen non-native insect species and five plant pathogens will become naturalized in the United States between 2000 and 2020." (Public Garden 2007)

Loss of biodiversity is recognized as the greatest long-term consequence of invasive species, second only to habitat loss as a primary cause of the decline of native species in the United States (Schulhof 2007). However, even native insects can cause devastation when plants are taken out of their natural range. The walnut twig beetle (*Pityophthorus* juglandis) has been identified as the vector of *Geosmithia morbida*, the fungus that causes 'Thousand Cankers Disease' (TCD) and mortality of eastern black walnuts (*Juglans*) (Appendix G).

Introduced destructive insects vary by region in the United States, with the Asian longhorned beetle (*Anoplophora glabripennis*) and the emerald ash borer (*Agrilus planipennis*) threatening in the east and northeast United States. The emerald ash borer (EAB), is a wood boring beetle native to Asia that feeds on and singularly kills both healthy and stressed ash (*Fraxinus* spp.). The emerald ash borer is known to occur in China, Korea, Japan, Mongolia, and the Russian Far East (Appendix A, Fig. 2). "A Chinese report indicates high populations of the borer occur primarily in *Fraxinus chinensis and F. rhynchophylla* forests. Other reported hosts in Asia include *F. mandshurica* var. *japonica, Ulmus davidiana* var. *japonica* (Japanese elm), *Juglans mandshurica* var. *sieboldiana*, and *Pterocarya rhoifolia* (Japanese wingnut)" (Schneeberger and Katovich). In North America, so far, the emerald ash borer has attacked only ash trees. Found near Detroit, Michigan in the summer of 2002 by a Michigan State University entomologist responding to a report of iridescent green beetles near ash trees, EAB has now spread to Ontario and Quebec, Canada as well as fifteen of the United States: Illinois, Indiana, Iowa, Kentucky, Maryland, Minnesota, Missouri, Pennsylvania, Virginia, West Virginia, Wisconsin, and most recently Tennessee (July 2010). In Philadelphia, PA, ash comprises six percent of the 2.1 million park and street trees. Many more outbreaks are likely as movement of infested firewood spreads the insect's range more quickly than the beetle would fly on its own. According to the USDA, removing infested and dead trees and planting replacements could cost local governments and homeowners $10.7 billion over twenty years. The value of ash trees in urban and forested areas is likely in excess of $300 billion (USDA Forest Service).

Beyond the dollar cost to governments and home owners, the cost to ecosystems in a time of accelerated climate change is higher and more difficult to repair. Public gardens, especially those adjoining natural areas, face severe losses in native biodiversity which, in turn, allows increased outbreaks of invasive plant species (Schulhof 2007), further disrupting native systems. Wise management in uncertain times is paramount to safeguard not only public access but also long-term management of collections.

Having never met this pest before, the symptoms were initially thought to be caused by ash yellows or a wilt disease. Initial strategies in Michigan were to contain infestations by eradicating all ash within a half-mile radius of any known borer activity. This plan did not work because it was predicated on a poor understanding of the insects' life cycle habits. Research by Robin Taylor of Ohio State University has shown that ten percent of any EAB populations are "super fliers, capable of covering distances exceeding six miles" (Egan 2007). Unexpected human allies assisted their spread with the movement of firewood and ash nursery stock.

Delaying the introduction of the emerald ash borer (EAB) into southeastern Pennsylvania is beyond the scope of this plan or anyone else's. Preparedness for southeastern Pennsylvania and the Morris Arboretum is now the objective, where preparedness is defined as a comprehensive strategy to assess resources, minimize risk and identify and contain infestations promptly, in a measurable and timely fashion. Holdings must be identified and guidelines prepared for education and response. Developing support to ensure adequate funding and physical resources to protect ash assets is vital. The following preparedness policy covers measures indicated for this purpose.

METHODS

The over arching goal is to protect the, *Fraxinus* species resource by minimizing the impact of emerald ash borer (*Agrilus planipennis* Fairemaire) at the Morris Arboretum of the University of Pennsylvania specific to:

- Collected exotic and native specimens containing valuable germplasm,
- Native ash species growing in natural areas

This plan's methodology may also be used to reduce and manage emerald ash borer infestations at the University of Pennsylvania.

The policy is divided into Pre-arrival and Post-arrival strategies. Pre-arrival strategies include four sections describing *Administrative Readiness, Educational Readiness, Technical Readiness,* and *Early Detection.* Following that, two sections will describe Post-arrival activities, divided into *Rapid Response*, *Management* and *Restoration* strategies.

I. Pre-Arrival Strategies

A. Administrative Readiness

1. Assemble working group: *The Morris Arboretum EAB Task Force* to be responsible to implement the Emerald Ash Borer management plan.
2. Select a task force chair person: The chair person will coordinate and implement the plan by administering policies and programs.
3. Inventory accessioned and non-accessioned ash on the Morris Arboretum grounds
4. Reference prepared plans; Assure policies are relevant and achievable
5. Identify resources
6. Understand government funding applications and requirements:

B. Educational Readiness

1. Issue media alerts
2. Pest Alert and ID cards available at the Plant Clinic
3. Educational programs for staff and volunteers
4. Educational programs for visitors, including children
5. Web page posted to the plant clinic web site

C. Technical Readiness

1. Draft centralized action plan
2. Classify tree inventory
3. Allow for systematic reporting
4. Follow USDA technical guidelines

5. Take advantage of new research and technology
6. Assure accuracy

D. Early Detection

1. First Detector Training
2. Scouting

II. Post-Arrival Strategies

A. *Rapid Response*

B. Management

1. No action taken
2. Pre-emptive removals
3. Cultural practices
4. Systemic pesticides
5. Bio-control
6. Disposal of infested wood
7. Community wood

C. Restoration

1. Ecosystem restoration
2. Diversity
3. Bio-control research
4. Resistant cultivars
5. Seed storage

RESULTS

The following policy is a dynamic document. It is in a form prepared to be removed and printed for use at the Morris Arboretum of the University of Pennsylvania. N.B. This report may be shared with the University of Pennsylvania, who is urged adopt this or a similar plan. According to the most current tree inventory, the university has 171 ash trees (Morris Arboretum Tree Inventory Files).

Morris Arboretum of the University of Pennsylvania

Official arboretum of the Commonwealth of Pennsylvania

Morris Arboretum Emerald Ash Borer Readiness Plan
May 2011

The emerald ash borer (EAB), *Agrilus planipennis* is a wood boring beetle native to Asia that feeds on and singularly kills both healthy and stressed ash (*Fraxinus* spp.). Since its identification in Michigan in 2002, millions of ash trees have been lost. As the EAB has been established in Pennsylvania since c.1997, it is imperative that the Morris Arboretum of the University of Pennsylvania have a plan for its imminent arrival and the significant threat to its collections and natural areas of the garden. Communication within the arboretum and among area landowners becomes ever more critical as more emerald ash borer infestations are found.

This readiness plan lays out comprehensive initiatives. It is instructive in assessing resources, minimizing risk, indentifying early infestations and partnering to treat and contain infestations as much as is feasible. Thereafter, a planning team will continue to update information as further research is published and cooperate to implement best management practices.

I. Pre-Arrival Strategies

A. ***Administrative Readiness:***

1. Assemble Working Group: *Morris Arboretum Emerald Ash Borer (EAB) Task Force:* This task force has been created to facilitate preparedness before the emerald ash borer is detected on Morris Arboretum grounds, and to manage and direct scouting, infestations, controls, removals and replanting after detection. This readiness plan's main objective is not eradication of this pest, but to attempt to delay its introduction and establishment and to minimize its impact at Morris Arboretum. The *Morris Arboretum EAB Task Force* will include the Morris Arboretum Director of Horticulture and Curator, the Associate Directors of Urban Forestry, the Chief Horticulturalist, the Morris Arboretum Arborist and the Plant Propagation Intern (Appendix A, Fig. 3).
2. Select a chair person: The chair person at Morris Arboretum will lead the task force and coordinate and implement the plan. The *Morris Arboretum EAB Task Force* will be supervised by the Gayle E. Maloney Director of Horticulture and Curator, a title currently held by Anthony Aiello. The chair person has the authority to delegate tasks to both the Education Department (Public Programs) and the Development Department for assistance in supporting the goals of the plan.
3. Inventory all Fraxinus species on Morris Arboretum grounds: There are approximately 111 ash trees on Morris Arboretum's grounds. Of these, the majority (51%) are non-accessioned native trees found in natural areas. Of those that are accessioned, 35 (32%) are exotic and 19 (19%) are native to North America (Appendix B)
4. Identify Budgetary Resources: Budget for protection (recurrent application of insecticides), or removal and replacement. This section is subject to discussion and approval by the *Morris Arboretum EAB Task Force.*
   a. Morris Arboretum Operating Budget:
   b. Government funding resources, applications and deadlines:

Effort will be made to develop funding for protection of valuable trees, for removals both pre-emptive and post senescent, to lead education for employees, volunteers and visitors, and to plan for replacement of lost trees, long-term plant diversification, and sustainability. Resources such as these ebb and flow as funds are available. When the emerald ash borer's population makes it necessary for increased funding for its management, external grants will be researched and written.

5. Reference prepared plans and assure policies are relevant and achievable:
    a. Plans from Morton Arboretum, of Lisle, Illinois, and plans from the states of Iowa, Minnesota, Wisconsin, and Pennsylvania have been thoroughly researched. Relevant information has been incorporated and positioned into the Morris Arboretum Emerald Ash Borer Readiness Plan.
    b. The Coalition for Urban Ash Tree Management fundamentally endorses ash tree conservation as a component of integrated pest management of the emerald ash borer in residential and urban landscapes (Appendix E). http://www.emeraldashborer.info/files/conserveash.pdf
6. Understand government funding applications and requirements:
   Since EAB management will incur unanticipated costs, it will be vital to secure additional funding from outside sources. The U.S. Forest Service provides competitive grants to nonprofits that may be available to Morris Arboretum for management and restoration following EAB infestation. The Morton Arboretum in Lisle, IL has joined with area mayors and other agencies to work together in a focused effort. It would be advantageous if the mayors' group in the Delaware Valley (Metropolitan Caucus) would come together to join resources.

B. Educational Readiness

Morris Arboretum EAB Task Force will take the lead in communicating current and accurate information quickly to support the technical team, thereby allowing early detection and intervention.

1. Issue media alerts: raise public awareness via media bulletins
2. Brochures, pest alerts, and wallet ID cards displayed and readily available
3. Educational programs
   Valuable information is available from "Emerald Ash Borer University", a collaborative effort jointly sponsored by Michigan State University, Ohio State University, and Purdue University. Information is given in the form of educational webinars that are available on demand at http://www.emeraldashborer.info/eab_university.cfm
    a. Educate professional horticulture and volunteer staff with current and accurate information.
    b. Educational programs for visitors
    c. Promote "Project Learning Tree" for school age children
       http://www.emeraldashborer.info/files/edpacket.pdf
    d. Morris Arboretum Urban Forestry School of Arboriculture curriculum
    e. Greater Philadelphia Gardens Collaborative forum
       http://www.greaterphiladelphiagardens.org/

1. Plant Clinic Initiatives
    a. Web page posted to the plant clinic web site (Appendix E)
    b. Include GDD information collected by the Plant Propagation intern: (emerald ash borers emerge at 550 GDD, simultaneous with bloom of black locust *Robinia pseudoacacia*)).

c. Bar introduction of ash plant material to the Morris Arboretum and to Plant Clinic unless contained securely.

2. Pay strict attention to firewood movement strategies
   a. Do not move ash firewood.
   b. Buy firewood at destination when necessary, leaving remainder behind

C. Technical Readiness

Technical Readiness will assure decisions, actions, and education initiatives are guided by the best and most current science.

1. Draft centralized plan of action (i.e. this readiness plan)
2. Allow for systematic reporting
   a. Plant propagation intern will scout regularly for emerald ash borer signs and symptoms. (e.g. increased wood pecker activity beginning after Thanksgiving into winter, including patchy bark loss from feeding).
   b. Log sheets for trained staff and volunteers will be accessible in the plant clinic for reporting purposes (Appendix C).
3. Classify accessioned and non-accessioned ash species belonging to the Morris Arboretum of the University of Pennsylvania (Appendix B). Categorizing inventory before impact will facilitate comparisons now and management later. The Morris Arboretum's curator, Anthony Aiello, has determined that existing numbers will be used for plants currently accessioned. If there are any unaccessioned plants placed on the 'Save' list, accessioning will be considered. For all other plants, a simple tagging system will work. If there are trees in the natural area previously tagged, those tags will be kept, as well as any new tags. Accessioned trees of value are considered critically important because of crucial germplasm or aesthetic significance. The following lists differentiation within the inventoried plants:
   a. Collected from wild: (germplasm of Asian species)
   b. Large mature trees
   c. Valued as part of design
   d. Non-accessioned trees in natural areas
   e. Some trees must be left unmanaged due to budgetary constraints. As there is no flagship ash tree in the garden, decisions will largely be based on staff and visitor safety. An inventory list has been prepared that covers all ash within the main garden, and paths in natural areas adjacent to paths and main roads (Appendix B).

D. Early Detection

The U. S. Forest Service monitors state wide, using purple traps and trap trees (Appendix D). On a more local basis, Morris Arboretum will perform regular visual scouting, as follows:

1. Scouting must be done on a regular basis. Survey forms for Morris Arboretum trained staff are available (Appendix C).
   a. Exit holes
   b. Canopy dieback
   c. Bark splits
   d. Epicormic growth
   e. Woodpecker activity
   f. Look-a-like insects/disease
   g. First Detector Training:
   h. Follow up on suspected sightings
2. Quarantines: No wood or ash nursery stock may be moved beyond state or federal quarantine boundaries. For example, although the state quarantines that fully

encompass Pennsylvania and Ohio allow ash material to be moved intrastate, it would violate federal quarantines to move ash material across state lines.

a. Entry or exit of ash nursery stock is prohibited except from inspected and compliant sources.
b. No ash plant material may be given as gifts outside quarantined areas.
c. All firewood used on Arboretum grounds or taken from the property for outside activities must be sourced as from a compliant facility, including Morris Arboretum. Pennsylvania's Department of Conservation and Natural Resources will establish compliant ash receiver sites, for which information is not yet available. (Reference Illinois' quarantines directives for familiarity with possible procedures (http://extension.entm.purdue.edu/eab/pdf/quarantines.pdf).
d. Since EAB control methods change over time, the Arboretum chairperson will review currently recommended control measures on the EAB website and make management decisions based on best EAB management practices.

II. Post-Arrival Strategies

A. Rapid Response

Call the Pennsylvania Department of Agriculture *1-866-253-7189*
or E-mail: *Badbug@state.pa.us*

B. Management

1. Follow established Pest Response Guidelines: The Department of Conservation and Natural Resources (DCNR) manages EAB infestations once a newly infested site has been identified and confirmed by the Pennsylvania Department of Agriculture. Management strategies are constantly updated with new research subsidized by the United States Forest Service Research Stations. All management must take a multi-faceted approach.
2. No Action Taken: If no action is taken and there are no efficacious EAB management techniques, all native ash trees will die and Fraxinus will become extinct. Exotic species from Asia have some ability to withstand attack from EAB but with high pest pressure, they may also succumb. The Environmental Protection Agency (EPA) has registered three systemic insecticides for control. These insecticides have been approved by the Coalition of Urban Ash Tree Conservation (www.emeraldashborer.info/files/conserve_ash.pdf), a group of university researchers, municipal arborists, and urban foresters who believe an integrated approach using good inventory methods, along with treatment and tactical removals will retain the integrity and value of the urban forest).
3. Preemptive Removals: In order to reduce insect pressure or to retain visual sightlines in the garden, some Fraxinus may be removed preemptively. Removal of infested trees is desirable and most advantageous in winter and early spring before the adults emerge to reduce population pressures. Review tree limb and branch collection programs and determine where such materials are currently being disposed. Cutting the trees and stacking the logs as firewood will not kill the beetles. If trees are to be removed, cutting and chipping them before May 1st is desirable to prevent adults from emerging.

4. Cultural Practices: Ash trees in areas where the borer is active must be mulched and watered during dry spells to avoid drought stress. This activity is one facet of integrated pest management.
5. Systemic Insecticides:
    a. Imidicloprid11,12,13,14 for trunk injection or soil application. Imidicloprid products can be used with a surfactant (Pentra-Bark) that opens lenticels, improving penetration through periderm. Atomization is not required, eliminating the possibility of drift.
    b. Dinotefuran (Safari, a neo-nicotinoid)[1,2,3,4] basal trunk bark or soil application. *Dinotefuran* products can be used with a surfactant (Pentra-Bark) that opens lenticels, improving penetration through periderm. Atomization is not required, eliminating the possibility of drift.
    c. Emamectin benzoate (TREEäge) for trunk injection only1,2,3,4
6. Bio-Control
    a. USDA rears three species of wasps as biocontrol agents for EAB, including two species that kill EAB larvae. Tetrastichus planipennisi (Yang) adults find and insert their eggs into EAB larvae, producing 56-92 offspring from a single EAB host. Spathius agrili behaves similarly except that the wasp eggs and developing wasps are attached to the outside of the EAB larvae. The developing wasps feed on and eventually kill the EAB larvae. Egg parasitoid, Oobius agrili, discovered in Jilin province, China in 2004, inserts their eggs into EAB eggs on ash bark. The developing wasps feed on and destroy the eggs. Bio-control is still in the research stage, and will become one more facet of integrated pest management.
    b. Cerceris fumipennis, a native ground-nesting wasp, can monitor and assist in EAB detection. This wasp does not significantly reduce EAB populations, but preys on the adult emerald ash borers and other native beetles, carrying the paralyzed beetles back to its burrow where they are stored as food for the wasp's larva.
7. Disposal of Infested Wood: Infested ash material must be de-barked to ½ inch depth below the bark (to sapwood), burned, buried, or double chipped to pieces less than one inch in two directions.
    a. As the Morris Arboretum is located within an EAB-quarantined area, any service provider contracted by the Arboretum must use disposal yards with a

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[11]Article by Hahn J, Herms, D. and McCullough, D. "Frequently Asked Questions Regarding Potential Side Effects of Systemic Insecticides Used to Control Emerald Ash Borer" http://www.emeraldashborer.info/files/Potential_Side_Effects_of_EAB_Insecticides_FAQ.pdf)

[12] Many arborists are reluctant to inject insecticides directly into trees, fearing adverse side effects but according to a two year study by Doccola and Smitley et al. (2011), "all trees successfully compartmentalized injection wounds."

[13] McCullough, Deborah (MSU) and Herms, Daniel (OSU) Webinar discussion of controls (2011) http://breeze.msu.edu/p39122319/?launcher=false&fcsContent=true&pbMode=normal

[14] See Appendix F: Guidelines for Cost of Treatment

current EAB compliance agreement in place. It will not be necessary for the Morris Arboretum to be concerned when crossing county boundaries for ash wood disposal (i.e. Northwestern Avenue that divides Philadelphia and Montgomery counties) due to whole Pennsylvania state quarantine. Therefore no compliance agreement will be required.

b. Work with Springfield Township to keep mulch yard free of pests; double grind all mulch and wood waste. Mulched pieces must be smaller than one inch in two directions.

8. Community Wood: Salvaging ash resource is a strategy beneficial to whole communities. "Removal and utilization of ash trees, either before or after an infestation, may help slow the spread of EAB and reduce EAB populations" (USDA Forest Service 2010). Wood can be used for known valuable forest products such as tool handles, furniture and basket making. This has proved a more economic use of ash wood compared with burning or landfill options. The Wood Education and Resource Center (WERC) has partially supported these efforts in the past. http://www.emeraldashborer.info/files/E-2940.pdf

C. Restoration

1. Research: Remove and replace lost *Fraxinus* with resistant species or varieties.
   a. Retrogressive Hybridization: Introgressive hybridization may produce hybrids similar to those bred for resistance to chestnut blight. In Gapinski's (2010) interview with R.A. Larson, nursery manager at The Dawes Arboretum in Newark, Ohio, he states that although *Fraxinus mandshurica* and *Fraxinus chinensis* are very resistant to emerald ash borer, they have both been found to be difficult to cross with North American plant species. The North American China Plant Exploration Consortium (NACPEC) a network of arboretums and botanical gardens that includes the Morris Arboretum focuses on collecting and preserving plant germplasm. Collections in China and Korea coincide with the native range of EAB (Appendix 1. Fig. 5).
   b. Transgenic Hybridization: Fraxinus exhibiting resistance to attack by the EAB is currently being researched by the USDA Forest Service (Du and Pujit) to propagate transgenic ash plants containing the *Bacillus thuringensis* (*Bt*) toxin specific to the EAB. *Bt* is a naturally occurring bacterium used in commercial biological preparations to control larval forms of agriculturally important insect pests. Future studies will be to examine the use of sterility genes to further modify transgenic ash in a way that would prevent their hybridization with native ash populations once introduced into the landscape.
2. Seed Collection: Seeds of the largest Fraxinus are currently being stored in Fort Collins, CO. According to the USDA (2009), some ash seed has been stockpiled in the past for conservation and timber purposes but, to date, there has little need to collect ash seed from the wild. Arrival of the EAB, however, has created the need to gather wild germplasm to be stored long-term for future research and restoration. Dave Ellis, of the Plant Genetic Resources Preservation Program at the National Center for Genetic Resources Preservation (1111 South Mason Street, Fort Collins, CO 80526 elvis@ars.usda.gov) has been collecting ash seed since 2006. See "Recommendations for the Collection, Storage and Germination of Ash (Fraxinus spp.) Seed" http://www.emeraldashborer.info/files/Fraxinuscollection.pdf

3. Diversification of Forest and Urban Canopy: Anthropogenic impacts continue to cause devastation to ecosystems world-wide, including southeastern Pennsylvania. Another incursion of an invasive wood boring insect forces a re-examination of species used, possibly over-used, in urban and suburban areas, and whether the choices on recommended tree planting lists are diverse enough to withstand future onslaughts of invasive pests. Not too far in the future, impacts *on Acer, Betulus, and Platanus*, susceptible to Asian long horned beetle (*Anoplophora glabripennis*), an insect causing damage in New England, will become more apparent. In this age of global marketing and trade, our urban forests must be resilient through superior planning and diversified plantings. Many tree species have limited ability to grow and prosper in the limited root spaces of city streets where *Fraxinus* has shown toughness and tolerance for these environments. In natural areas, ash is a pioneer species, able to germinate in canopy openings and tolerate shade when young. Without this genus, our natural areas will need long-term sustainable management to enable viable ecological economies. Planting diversified alternative species is the only way to help mitigate the profound impact the loss of ash species will have.

a. Wildlife Trees: Where tree-related hazards are low or nonexistent, senescent ash trees will be left standing for wildlife, to remain part of the ecosystem community as long as possible (see Discussion below).
b. Remnant Stumps: Remnant stumps in natural areas can be left to re-sprout for education and research. This approach will also accomplish the goal of retaining soil structure and health. The EAB kills the living above-ground portion of trees, not the roots. Therefore, root sprouts will continue to return, growing to a size attractive to emerald ash borers before succumbing again, similar to the chestnut tree resprouting still seen in eastern North America.

[End of Morris Arboretum Emerald Ash Borer Readiness Plan Document]

DISCUSSION

Fraxinus americana, (*Oleaceae*) is a good example of the value of native ash to North American forest ecology. "White ash is a pioneer species… characteristic of early and intermediate stages of succession. Although mature white ash is classified as shade intolerant, the seedlings are shade tolerant. A seedling can survive at less than 3 percent of full sunlight for a few years allow(ing) the species to regenerate in gaps. White ash is an important source of browse and cover for livestock and wildlife. The samaras are good forage for the wood duck, northern bobwhite, purple finch, pine grosbeak, fox squirrel, and mice, as well as many other birds and small mammals. White ash is browsed mostly in the summer by white-tailed deer and cattle. The bark of young trees is occasionally used as food by beaver, porcupine, and rabbits" (Griffith 1991). The white ash also forms trunk cavities readily if the top is broken and its large size at maturity makes it valuable for primary cavity nesters such as red-headed, red-bellied, and pileated woodpeckers. Once a cavity is completed, the hole becomes an excellent habitat for secondary nesters such as wood ducks, owls, nuthatches, and gray squirrels (Griffith 1991).

The wood of ash species is exceptional: hard and light, yet flexible and suitable for many uses in commerce such as basket making, tool handles, and fine furniture (Boom and Kleijn). Ash species are urban tolerant, making them good street trees and have been used to a great extent, significantly as a replacement for the elm. Approximately sixty species occur throughout the northern hemisphere, distinguished between "flower" ashes and "leaf" ashes, the former blooming a month later with petals that are lacking in the leaf ash form (Boom and Kleijn). Of the American ashes, the white ash (*Fraxinus americana*), and green ash (*Fraxinus pensylvanica*) are most common and important in cultivation.

History of EAB in the US

EAB, *Agrilus planipennis* (Fairmaire) was first detected in July 2002 in southeastern Michigan and shortly thereafter in neighboring Windsor, Ontario, Canada. It is believed that EAB arrived in ash crating or pallets from China at least fifteen to twenty years ago (Herms 2007). As a non-native in North America, this borer does not have natural controls such as parasites, predators or disease that it has in its native range. This vastly increases its destructive ability in North America since host plants have not evolved effective defenses against them. With the advantage of anonymity and having gained access to an unlimited store of most desirable resource, EAB populations have soared. The EAB attacks all North American native ash populations from small saplings to mature forest trees. They attack healthy trees as well as weak, vulnerable ones, making infestations particularly devastating. Infestation of known ash species includes green ash (*Fraxinus pensylvanica*), white ash (*F. Americana*), black ash (*F. nigra*) and blue ash (*F. quadrangulata*). Ash species primarily attacked in Asia include Manchurian ash (*F. mandshurica*) and Chinese ash (*F. chinensis*). It is not yet known how resistant Asian species will be in North America where pressure will be greater.

Taxonomy and Life Cycle

The emerald ash borer, an exotic invasive wood boring insect, is a member of the order *Coleoptera* (*Buprestidae*), that also includes the native two-lined chestnut borer *(Agrilus bilineatus* Weber*),* the bronze birch borer *(Agrilus anxius* Gory) and the ash lilac borer (*Podosesia syringae* Harr). As a group, these beetles feed on a wide variety of diets, inhabit all terrestrial and fresh-water environments, and exhibit a number of different life styles but all

undergo complete metamorphosis where the young have a different form from the adult. Many borer species are herbivores, variously adapted to feed on the roots, stems, leaves, or reproductive structures of their host plants (Meyer 2011). Borers only attack living trees, dead trees not being colonized.

EAB life stages, as in all beetles, include egg, larvae, pupa, and adult. Individual adults live for a few weeks, during which females, after mating, locate the upper canopy of the nearest large ash tree and lay individual eggs in bark crevices on the trunk and branches. Seven to ten days later, larvae from hatched eggs chew through the bark into the cambium, where they feed for several weeks in the phloem and outer sapwood. Extensive "S"-shaped galleries are formed, becoming progressively wide as the insects enlarge. As noted by Peters and Iverson (2009), most trees had exit holes on the south and west aspects of the trees. It is thought that the warmth of sunlight aids in the development of larvae. The galleries are packed with fine, sawdust-like frass and often extend 7.87 to 11.81 inches in length (Schneeberger and Katovich 2007). By autumn, feeding is completed and the prepupal larvae overwinter in the thick outer bark of the tree. In late April or May pupation begins. "Newly enclosed adults often remain in the pupal chamber for 1 to 2 weeks before emerging head first through a small, 0.12- to 0.16-inch D-shaped exit hole" (Schneeberger and Katovich).

Typically producing one generation per year, some larvae require two seasons to mature. This is particularly true of early infestation in a healthy ash (McCullough and Siegart). Adult borers emerge in late May at 548 growing degree days (GDD), (beginning January 1, base 50) along with the onset of bloom of black locust (*Robinia pseudoacacia*) at 550 GDD. Adult beetles emerge from ash trees throughout the summer but are mostly present in June and July. Insect development and, therefore, adult emergence, is temperature dependent. Adults are most active on warm, sunny days (Schneeberger and Kotovich). Damage by an individual larva is minimal, but, as a tree is repeatedly attacked, the population buildup of thousands of insects quickly overwhelms the ability of the tree to defend itself. Tree decline and death can be rapid, but it often takes several years for EAB populations to build enough for tree symptoms to appear. According to Schneeberger and Katovich, these factors may help explain why new infestations are often undetected for several years. There is minimal evidence of beetle infestation in the first year until the canopy begins to show signs of dieback in the second year. During the second growing season after invasion, the tree declines quickly and is usually dead by the third (IL EAB readiness Plan, Makra, Ed. 2006)

Ash trees are a resilient species and can overcome small amounts of cambial damage. However, as larval numbers escalate, increased woodpecker activity may be noticeable beginning in early winter (after Thanksgiving). As damage increases during the next season, more reparative tissue is formed, leading to distinct bulges in the trunk which soon splits as internal growth exceeds the capability of bark to cover it. Soon after, as nutrient and water supply is cut off to the upper canopy, epicormic branches appear in a desperate effort to restore foliage for photosynthesis of sugars. Borer exit holes are initially found in the upper canopy and difficult to see. By the time exit holes, bark cracks, and epicormic branches are evidenced at eye level, the likelihood of tree survival is very low. There must be at least fifty percent cambial integrity remaining in an untreated ash tree for a positive response to systemic controls to be expected. Any insecticide must be able to move up the tree into all tissues in order to be successful (McCullough 2011).

Visual symptoms associated with EAB infestations are nearly identical to those often seen on ash that are infested or infected by other commonly found pests and diseases. For example, crown dieback can result from multiple stressors including drought stress, soil compaction, ash yellows, or verticillium wilt. Therefore, as Wisconsin's EAB Information Source advises, it is important to look for a combination of at least two or more symptoms or signs https://onlineservices.datcp.wi.gov/eab/index.jsp. "A rosette or witches broom on ash [is] caused by the ash yellows phytoplasma. Ash trees affected by ash yellows develop this classical dense, highly branched but stunted shoots and foliage which is distinctly different from the lush, large shoots on trees affected by EAB"(Roberts 2007).

Economic and Ecological Impact

EAB has the potential to eliminate *Fraxinus* from North America, a dominant genus in forests and cities, creating dramatic changes to plant and animal communities as well as entire ecosystems. Devastation in Canada and US: "…killed tens of millions of ash trees in southeastern Michigan alone, with tens of millions more lost in Illinois, Indiana, Kentucky, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, Tennessee, Quebec, Virginia, West Virginia, and Wisconsin." (http://www.emeraldashborer.info/) In Pennsylvania, ash comprises 3.6% of the forests, with more than 300 million trees throughout the state (about 10,800,000 ash trees) http://www.dcnr.state.pa.us/forestry/fpm_invasives_eab.aspx

It has been determined that EAB is officially the most destructive insect pest to arrive in North America in terms of dollar cost and number of trees lost. An economic study done in 2010 projecting the spread and ensuing costs to remove and replant lost trees over ten years (2009-2019), determined the cost to be at least ten billion dollars in urban areas alone. If suburban areas are included, that cost will exceed twenty billion dollars (McCullough).

CONCLUSION

Ecosystems in the 21st century are threatened constantly for many reasons, EAB from Asia being only the latest of many yet to come. Development of a plan to reduce the imminent threat to ash populations at the Morris Arboretum favors everyone who uses the beauty of the gardens for pleasure or takes advantage of its educational wealth. Ash resources can survive with an integrated pest management approach using cultural, systemic and bio-controls in the short-term and with the addition of hybridized introductions in the long-term. This readiness plan will help delay its introduction and establishment and minimize its impact at the Morris Arboretum.

There are multiple desired outcomes achievable through this management plan: preparedness for detrimental effects through education and technical strategies, a management plan providing tools and resources necessary to respond to invasion, and approaches to retain ecosystem function and to restore lost resources.

As many as twenty-one species of *Fraxinus* are distributed throughout the United States. EAB is known to feed on all four major ash species in the northeast, but whether it will feed on other ash species or adapt to other areas in the US is not well known at this time and will not be known until or if the beetle arrives in [other] regions (Parsons 2008). Because ash seedlings and small trees are very common in forests, small woodlots, and rights of way, it unlikely that EAB

will ever disappear from any area where it has become established (Herms et al. 2009). In this age of global marketing and trade, our urban forests must remain resilient through superior planning, diversified plantings and proper management. Natural areas need long-term sustainable management in order to enable viable ecological economies.

REFERENCES

Bauer, L. and Liu, H. 2006 "*Oobius Agrili (Hymentoptera: Encyrtidae)*, A Solitary Egg Parasitoid of Emerald Ash Borer from China". USDA Forest Service, Northern Research Station. http://nrs.fs.fed.us/pubs/jrnl/2007/nrs_2007_bauer_002.pdf Accessed 23 March 2011.

Bonte D, et al. 2010 "Local Adaptation of Aboveground Herbivores toward Plant Phenotypes Induced by Soil Biota" PLoS ONE 5(6): Accessed 1.7.11.

Boom, B. K. and Kleihn, H. 1966. The Glory of the Tree. Doubleday and Company Inc: New York.

Bowers, Lisa. "Forest Health: Monitoring our Walnuts." Ohio Department of Natural Resources, Department of Forestry. http://www.ohiodnr.com/LinkClick.aspx?fileticket=cHEIm%2FPkNt0%3D&tabid=5320 Accessed 25 April 2011.

Doccola, Joseph J. et al. "Tree Wound Responses Following Systemic Insecticide Trunk Injection Treatments in Green Ash (*Fraxinus pensylvanica* March.) as Determined by Destructive Autopsy". Arboriculture and Urban Forestry. 37(1): 6-12.

Du, N. and Pijut, P. Isolation and Characterization of an AGAMOUS homolog from *Fraxinus pensylvanica*. USDA Forest Service. (manuscript in preparation for publication). http://www.nrs.fs.fed.us/disturbance/invasive_species/eab/control_management/eab_resistent_ash. Accessed 4 April 2011.

Egan, Dan. "Are We Barking up the Wrong Tree?" Milwaukee Journal Sentinel. 3 March 2007. Accessed 8 February 2011.

Eggen, Donald A, Liu, Houping and Hall, Thomas. "Managing Invasive Forest Pests in Pennsylvania" Pennsylvania Department of Conservation and Natural Resources. http://www.continentalforestdialogue.org/ Accessed 16 February 2011.

Gapinski, Andrew T. 2010. Preparing plant Collections for Biologic Invasions: A Study of the Effects of Emerald Ash Borer (Agrilus planipennis Fairemaire) Through Case Study Analysis." master's thesis. University of Delaware. Newark, DE.

Griffith, Randy S. 1991. "*Fraxinus americana"* in: "Fire Effects Information System", [Online]. USDA, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. http://www.fs.fed.us/database/feis. Accessed 2.11.2010.

Herms, Daniel A. "What is an Emerald Ash Borer?" Ohio State University Extension Factsheet: Entomology.Ohio State University. Accessed 8 February 2011.

Herms, D.A., et al. 2009. "Insecticide Options for Protecting Ash Trees from Emerald Ash Borer", North Central IPM Center Bulletin. Accessed 23 March 2011.

Internet Sacred Texts Archive. "Trees of the World." http://www.sacred-texts.com/earth/boe/boe16.htm. Accessed 10 September 2011.

Lowenstein, F. and Springborn, M. 2009. "Trade and Forest Invasives" National Center for Ecological Analysis and Synthesis. Fall Update. Accessed 16 Feb. 2011.

Maher, K. "The Vexing Bugs in the Global Trading System" The Wall Street Journal. 15 Jan 2010. Accessed 10 September 2010.

Makra, Edith (ed). "Illinois Department of Natural Resources Readiness Plan" Illinois Department of Natural Resources. www.illinoiseab.com Accessed 1 November 2010.

Meyer, J. General Entomology 425. College of Agriculture and Life Sciences, North Carolina State University. www.cals.ncsu.edu 3 Feb. 2011. Accessed 4 February 2011.

McCullough, Deborah G., and Herms, Daniel. 2011. "Options to Protect Landscape Ash Trees from Emerald Ash Borer (Do Something or Kiss your Ash Goodbye!)" USAD Forest Service Webinar. Accessed 6 April 2011.

McCullough, D. and Siegart N. 2007. "Using Girdled Ash Trees Effectively for Emerald Ash Borer Detection, Delimitation and Survey." Michigan State University, Michigan Technological University, USDA Forest Service. Accessed 1 April 2011.

Morglia, Skip and Boyt, David. 2011. "Thousand Cankers Disease: A Red Alert for Black Walnut." Alabama Cooperative Extension System: Urban and Community Forestry. http://www.aces.edu/ucf/BlackwalnutThousandCankerDisease.php. Accessed 20 April 2011.

Nentwig, W. 2007. "Biological Invasions; Why it Matters". Springer-Verlag: Berlin-Heidelberg.

Nutter, M. "Mayor Nutter Announces Plan to Transform Five Hundred Acres into Public Green Space." Mayor's Press Releases. 7 December 2010. Accessed 6 April 2011. http://cityofphiladelphia.wordpress.com/2010/12/07/mayor-nutter-announces-plan-to-transform-500-acres-into-public-green-space. Accessed 31 March 2011.

Olsen, Lars J. "The Economics of Invasive Terrestrial Species: A Review of the Literature" Agricultural and Economics Review 35/1: 178-194. Accessed 19 April 2011.

Peters, M., Iverson, L.and Sydnor T.Davis. "Emerald Ash Borer (*Agrilus planipennis):* Towards a Classification of Tree Health and Early Detection" Ohio Journal of Science.109 (2): 12-25.

Raupp, Michael J. 2010. "Reduced Risk Insecticides and Non-Chemical Approaches for Managing Invasive Insect Pests. 46th Annual Penn-Del I.S.A. Shade Tree Symposium Lancaster, PA. 1 February 2011.

Roberts, D. "Ash Trees Decline" Michigan State University Extension. www.anr.msu.edu/robertsd/ash/decline.html. Accessed 15 Feb. 2011.

Roberts, David 2007 Emerald Ash Borer, the Michigan Experience. DVD. New Day Productions, Producer

Ruiz, G.M. and Carlton, J.T. (ed.) 2003. Invasive Species: Vectors and Management Strategies. Island Press.

Scandinavian Books. "Vikings in Edda and Viking Sagas" Accessed 8 March 2011. http://www.scandinavianbooks.com/vikings/viking-saga-literature.html

Schulhof, Richard "Managing Biological Invasions: Introduced Pests and Pathogens." Public Gardens 22(4):26-29.

USDA Animal and Plant Inspection Service-Plant Health/Plant Pest Information 2010. "Emerald Ash Borer". Accessed 4 Feb. 2011.

USDA–APHIS/ARS/FS. 2010. Emerald Ash Borer, *Agrilus planipennis* (Fairmaire), Biological Control Release Guidelines. USDA–APHIS–ARS-FS, Riverdale, Maryland.

USDA-APHIS. 2005. Emerald Ash Borer: The Green Menace. Video. Detroit Public Television, Producer.

USDA Forest Service "A Threat to North American Ash Trees". Northeastern Area State and Private Forestry. Accessed 28 Dec. 2010.

USDA Forest Service. 2010. "Integrated Program Strategy for Reducing the Adverse Impacts of Emerald Ash Borer throughout the Northeastern Area". Northeastern Area. State and Private Forestry, Forest Health and Economics. Accessed 18 January 2011.

USDA Forest Service. 2009. "Major Forest Insect and Disease Conditions in the United States 2007". FS-919. Accessed 14 March 2011.

Williams R. D. 1990 *Juglans nigra* L., Black walnut. In: Burns RM, Honkala BH (tech coords)

"Silvics of North America". Hardwoods. Vol 2 USDA Forest Service Agricultural Handbook 654, Washington, pp 386-390.
Yao, S. "Public Gardens and ARS Working Together in Plant Preservation" Agricultural Research. Nov-Dec 2010.

APPENDIX A: Figures 1-6

Fig.1. Yggdrasil of Norse mythology

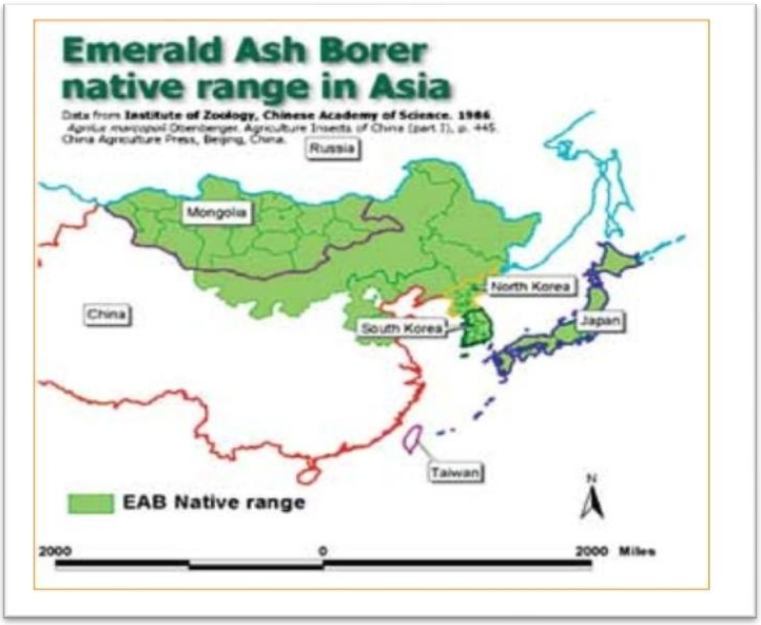


Fig. 2. Emerald Ash Borer native range

Fig.3. Emerald Ash Borer (EAB) Readiness Task Force

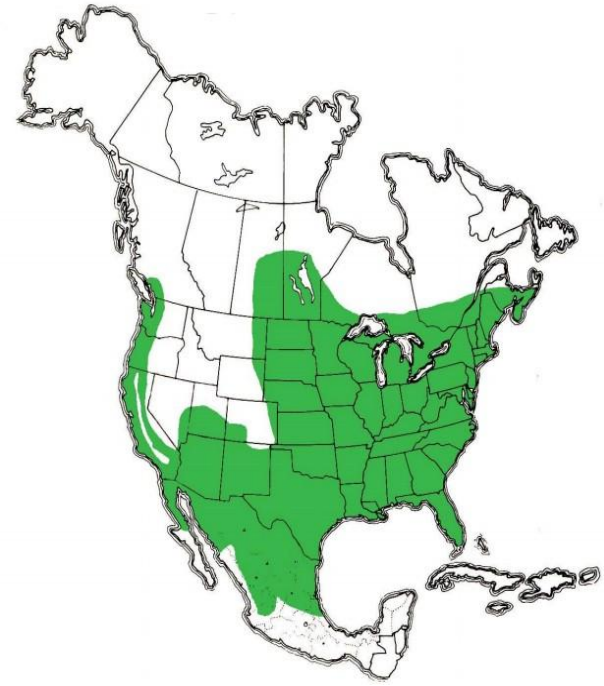


Fig.4. Range of native *Fraxinus* spp. in North America
USDA Forest Service Map
http://plants.usda.gov/java/profile?symbol=FRAM2p

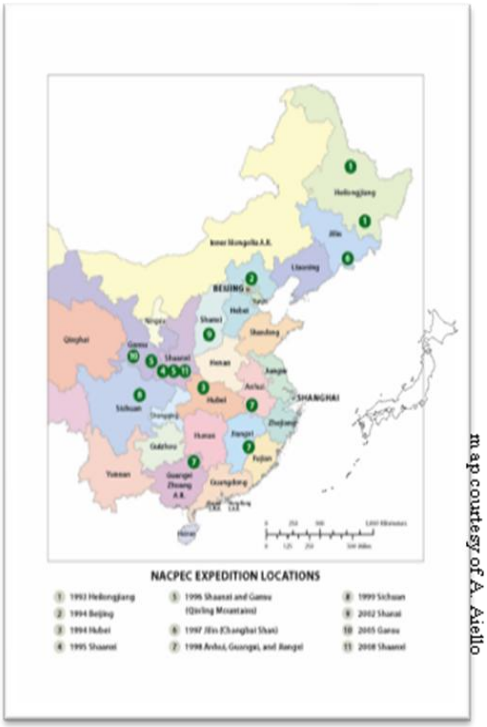


Fig.5. North American China Plant Exploration Consortium (NACPEC) a network of arboretums and botanical gardens focus on collecting, and preserving plant germplasm from all over the world.

APPENDIX B: Tree Inventory and Classification Spreadsheet

Accession #	EAB #	AB #	2 B Acc. ?	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*	Treat
2006-094*A				Fraxinus americana	American ash	N12		53	29	35				
32-2411*A				Fraxinus americana	white ash	D17		99						✓
54-0607*A				Fraxinus americana	white ash	E19		103						✓
54-0751*A				Fraxinus americana	white ash	F18		132					over pedestrian walkway	
54-1079*A				Fraxinus americana	American ash	H10		144					hollow shell w/ stump sprouts (+ catalpa within)	
82-063A				Fraxinus americana	American ash	F8	3'	109						
39-8557A				Fraxinus americana 'Ascidiata'		F7		48	48				very poor	
53-237C				Fraxinus americana 'Ascidiata'		F8		60	86					
2000-348*C				Fraxinus americana var. biltmoreana	Biltmore ash	G17							new planting: not assessed	✓
94-644C				Fraxinus bungeana	Bunge ash	H8	18"	19	12	8	8			
81-0504I				Fraxinus chinensis var. rhynchophylla	Korean ash	F7		41						
81-0504K				Fraxinus chinensis var. rhynchophylla	Korean ash	F7		38						
81-0504M				Fraxinus chinensis var. rhynchophylla	Korean ash	F7		36						
81-0504O				Fraxinus chinensis var. rhynchophylla	Korean ash	F7		16						
81-504*C				Fraxinus chinensis var. rhynchophylla	Korean ash	B21	3'	56						
81-504*D				Fraxinus chinensis var. rhynchophylla	Korean ash	B21	3'	68					no label	
81-504*G				Fraxinus chinensis var. rhynchophylla	Korean ash	B21	3'	60						
81-504F				Fraxinus chinensis var. rhynchophylla	Korean ash	F8	18"	23						
81-504H				Fraxinus chinensis var. rhynchophylla	Korean ash	F7		23	18					

Accession #	EAB #	AB #	2 B Acc. ?	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*	Treat
81-504J				Fraxinus chinensis var. rhynchophylla	Korean ash	F8		35					PI on trunk	
99-045A				Fraxinus chinensis var. rhynchophylla	Korean ash	J9		10						
99-045B				Fraxinus chinensis var. rhynchophylla	Korean ash	J9		11						
99-045C				Fraxinus chinensis var. rhynchophylla	Korean ash	J9		9						
37-7690A				Fraxinus holotricha	Balkan ash	F9		132						
97-261A				Fraxinus mandchurica	Manchurian ash	J9		10						
97-261B				Fraxinus mandchurica	Manchurian ash	J9		14						
99-046B				Fraxinus mandchurica	Manchurian ash	H9		15						
99-046C				Fraxinus mandchurica	Manchurian ash	H9		12						
2000-125A				Fraxinus 'Northern Gem'	Northern Gem ash	H9	18"	26						
2000-125B				Fraxinus 'Northern Gem'	Northern Gem ash	H9		15						
56-260A				Fraxinus ornus	flowering ash	K6	2'	17	29				remove:hollow decayed base with sucker	
91-014A				Fraxinus ornus	flowering ash	K6	base	46						
92-175*B				Fraxinus ornus	flowering ash	L16		32						
92-175*C				Fraxinus ornus	flowering ash	C20		42						
92-175*F				Fraxinus ornus	flowering ash	B20	4'	21						
92-175*G				Fraxinus ornus	flowering ash	E21		26						
92-175*H				Fraxinus ornus	flowering ash	J23-BED-8		25						
93-102*A				Fraxinus ornus	flowering ash	E19	18"	35	22					
93-102B				Fraxinus ornus	flowering ash	K7	3'	26	14	14	13	12	smooth bark	
93-108*A				Fraxinus ornus	flowering ash	L14		23						
32-2811*A				Fraxinus pennsylvanica	red ash	B20		95						✓
54-0608*A				Fraxinus pennsylvanica	red ash	D17		105						✓
81-280*A				Fraxinus pennsylvanica	red ash	F20		19	47					✓
75-141A				Fraxinus pennsylvanica var. lanceolata		G6		83						
36-4980*B				Fraxinus quadrangulata	blue ash	J10		55						
48-819B				Fraxinus quadrangulata	blue ash	G9		48						
94-155*B				Fraxinus sieboldiana	Siebold ash	L17	base	11						

Accession #	EAB #	AB #	2 B Acc. ?	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*	Treat
94-155D				Fraxinus sieboldiana	Siebold ash	K6							new planting : not assessed	
2001-069*A				Fraxinus texensis	Texas ash	H17							new planting : not assessed	✓
2002-197A				Fraxinus sp.	ash	H2		39	36					
2006-089*A				Fraxinus sp.	ash	P12		66						
2006-112*A				Fraxinus sp.	ash	N12		57						
82-064A				Fraxinus sp.	ash	F8	18"	108					old veteran, +Lonicera + groundhog	
82-065A				Fraxinus sp.	ash	F8		79						
	401			Fraxinus sp.	ash	K2		45						
	402			Fraxinus sp.	ash	K2		34	46	14				
	403			Fraxinus sp.	ash	H1		18						
	404			Fraxinus sp.	ash	H1		17	16					
	405			Fraxinus sp.	ash	H1		15						
	406			Fraxinus sp.	ash	H1		18						
	407			Fraxinus sp.	ash	H1		29						
	408			Fraxinus sp.	ash	H1		9						
	409			Fraxinus sp.	ash	G1		36						
	410			Fraxinus sp.	ash	E4		52						
	411			Fraxinus sp.	ash	H1		24						
	412												tag not used	
	413												tag not used	
	414			Fraxinus sp.	ash	E3		65						
	415			Fraxinus sp.	ash	E4		68						
	416			Fraxinus sp.	ash	E4		37						
	417			Fraxinus sp.	ash			72						
	418			Fraxinus sp.	ash	F5		66						
	419			Fraxinus sp.	ash	E5		15						
	420			Fraxinus sp.	ash	E5		25						
	421			Fraxinus sp.	ash	E8		38						
	422			Fraxinus sp.	ash	F6		26	28	88				
	423			Fraxinus sp.	ash	F6		32						
	424			Fraxinus sp.	ash	F11		24						
	425			Fraxinus sp.	ash	E6		56	34	39				
	426			Fraxinus sp.	ash	G16		80						
	427			Fraxinus sp.	ash	G17		102						

Accession #	EAB #	AB #	2 B Acc. ?	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*	Treat
	428			Fraxinus sp.	ash	G17		18					wound at 5', borer holes	
	429			Fraxinus sp.	ash	G16		54						
	430			Fraxinus sp.	ash	G16		60						
	431			Fraxinus sp.	ash	G16		95						
	432			Fraxinus sp.	ash	G16		44						
	433			Fraxinus sp.	ash	F17		64						
	434			Fraxinus sp.	ash	G17		85						
	435			Fraxinus sp.	ash	G17		69						
	436			Fraxinus sp.	ash	F16		90					CR- bulge/decay where limb ripped out @ 10'	
	437			Fraxinus sp.	ash	F16		42						
	438			Fraxinus sp.	ash	F16		76						
	439			Fraxinus sp.	ash	H17		72						
	440			Fraxinus sp.	ash	H17		62						
	441			Fraxinus sp.	ash	G16		47						
	442			Fraxinus sp.	ash	E6		62						
	443			Fraxinus sp.	ash	E7		82						
	444			Fraxinus sp.	ash	E7		59	65	39				
	445			Fraxinus sp.	ash	E7		89						
	446			Fraxinus sp.	ash	E7		36	42					
	447			Fraxinus sp.	ash	E7		56						
	448			Fraxinus sp.	ash	E7		36						
	449			Fraxinus sp.	ash	E7		52						
	450			Fraxinus sp.	ash	E7		59						
	451			Fraxinus sp.	ash	E7		72						
	452			Fraxinus sp.	ash	E7		22						
	453			Fraxinus sp.	ash	E7		18	24	36				
	454			Fraxinus sp.	ash	F7		48	33					
	455			Fraxinus sp.	ash	E8		60	79					
	456			Fraxinus sp.	ash	E8		78						
	457			Fraxinus sp.	ash	E8		32						
	458			Fraxinus sp.	ash	E8		55						
	459			Fraxinus sp.	ash	E8		43						
	460			Fraxinus sp.	ash	E8		21					grape vine stems	

Accession #	EAB #	AB #	2 B Acc. ?	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*	Treat
	461			Fraxinus sp.	ash	E8		56						
	462			Fraxinus sp.	ash	G9		77					lg. hollow base 15' resprouting; remainder fallen	
	463			Fraxinus sp.	ash	E8		70						
	464			Fraxinus sp.	ash	E8		58						
	465			Fraxinus sp.	ash	E8		69						
	466			Fraxinus sp.	ash	E8		40	25	35				
	467			Fraxinus sp.	ash	E8		47						
	468			Fraxinus sp.	ash	E8		64						
	469			Fraxinus sp.	ash	E8		50						
	470			Fraxinus sp.	ash	E8		50						
	471			Fraxinus sp.	ash	F9		44						
	472			Fraxinus sp.	ash	F9		27						
	473			Fraxinus sp.	ash	F9		17	14					
	474			Fraxinus sp.	ash	F9		27	24					
	475			Fraxinus sp.	ash	F9		13						
	476			Fraxinus sp.	ash	G9		41						
	477			Fraxinus sp.	ash	H9		56						
	253	253		Fraxinus sp.	ash	G11		117					AB Project #	
	479			Fraxinus sp.	ash	E8		28	46				inaccessible: no tag applied	
	480			Fraxinus sp.	ash	G11		128						
	481			Fraxinus sp.	ash	F11		42	16	19	19			
	482			Fraxinus sp.	ash	H16		76						
	483			Fraxinus sp.	ash	H16		57						
	484			Fraxinus sp.	ash	H16		44						
	485			Fraxinus sp.	ash	H16		84						
	486			Fraxinus sp.	ash	H16		64						

Accession #	EAB #	AB #	2 B Acc. ?	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*	Treat
	487			Fraxinus sp.	ash	H16		144					HAZARD TREE:DEAD; tree is 50'(H): <35' to path belowground bulging upper side	
	488			Fraxinus sp.	ash	H16		52						
	489			Fraxinus sp.	ash	G16		86						
	490			Fraxinus sp.	ash	H16		30					canopy difficult to see	
	491			Fraxinus sp.	ash	H16		56						
	492			Fraxinus sp.	ash	H16		49						
	493			Fraxinus sp.	ash			106					large lower trunk cavity creek side	
	494			Fraxinus sp.	ash	G16		58						
	495			Fraxinus sp.	ash	G16		45						
	496			Fraxinus sp.	ash	G16		38	25					
	497			Fraxinus sp.	ash	F16		68						
	1254			Fraxinus sp.	ash	G12		34	27	30				
	1255			Fraxinus sp.	ash	G13		141	31					
	1256			Fraxinus sp.	ash	G13		120	16					
	1257			Fraxinus sp.	ash	G13		17						
	82	82		Fraxinus sp.	ash	G12		124					AB Project #; hollow; ash anthacnose	
	262	262		Fraxinus sp.	ash	G11		124					AB Project #	
	1258			Fraxinus sp.	ash	H12		19					yellow ribbon	
	1259			Fraxinus sp.	ash	H14		15						

APPENDIX C: Emerald Ash Borer First Detector Survey Form

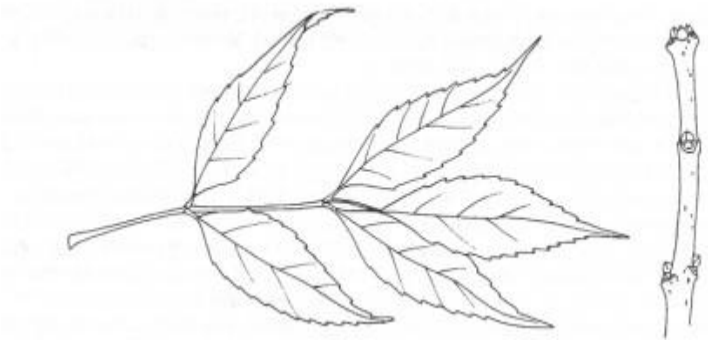
Ash or *Fraxinus* spp. belong in *Oleaceae* or the olive family. They are deciduous trees that leaf out very late in the spring.

Leaves: opposite, compound, 5-7 lance-shaped to oval leaflets, rounded teeth at the margin (white ash) or sharply toothed (green ash); leaves are thick, almost leathery.
Leaf Scar: *Fraxinus americana,* white ash; U-shaped scars on twigs with a lateral bud above
Fraxinus pensylvanica, green ash: D-shaped scars on twig ('D' is lying on its side) with a lateral bud above.
Twigs: **s**tout, rounded, smooth, grayish or greenish-brown often with a slight bloom; flattened at nodes at right angles to leaf scars.
Flowers: small and inconspicuous on separate male and female trees.
Seeds: are dry samaras shaped like canoe paddles.
Bark: gray to gray brown, furrowed into diamond shaped areas separated by narrow interlacing ridges.


*Paul Wray, Iowa State University

▲ ash bark

▲ white ash leaf and twig



▲ green ash leaf and twig

Look for signs and symptoms of EAB damage (start with ash trees that have poor overall health).
Are there any EAB signs listed below that can be observed? Use the table on the next page to check off the symptoms you observe.

Morris Arboretum: Emerald Ash Borer First Detector Survey Form

• **Crown thinning** – tree branches dying from the top down, especially high in the crown.

• **Woodpecker damage** – on the tree's trunk and branches. Increased activity may be noted in early winter, after Thanksgiving.

• **Small D-shaped holes** – (1/8 inch) indicating adult EAB exit sites (flat on one side, but can be oriented in any direction).

• **S-shaped or serpentine tunnels** – just under the bark, sometimes with larvae in them.

•**Bark Splits** - after heavy larval tunneling vertical splits in the bark can occur. This can sometimes reveal the tunnels under the bark.

• **Trunk sprouts** - leafy sprouts growing from the trunk or base of the tree

• **Adult EAB** – metallic green, ½ inch long, bullet-shaped beetles about 1/8 inch wide (pictures left and middle)

• **EAB larva** – white, inch-long flat "worms" with distinct bell-shaped segments (picture on right)

Morris Arboretum: Emerald Ash Borer First Detector Survey Form

1) Surveyor name and contact information:

2) Date(s) of survey

3) Tree Information

	Name of tree or accession number	Location in Garden	Crown thinning/ Branch dieback	Wood pecker activity	D-shaped exit holes	Serpentine galleries	Vertical bark splits	Trunk sprouts	Sample
1									
2									
3									

Submit completed form to Plant Clinic
(May 2011)

APPENDIX D: Purple Traps and Trap Trees

1. Adult Purple Traps

Because emerald ash borers are difficult to detect in the early stages of ash tree infestation, the U.S. Forest Service uses sticky traps to monitor new areas for possible invasion. Traps are placed on a grid about twenty-five feet from the edge of a woodlot or forested area. These consist of triangular purple traps (12" x 24") made out of corrugated plastic panels embedded with a volatile compound (one lure, a green leaf alcohol, is a primary volatile associated with ash leaves; the other lure, Manuka oil, contains many of the chemicals emitted by ash bark and wood, simulating a stressed tree). The trap is covered with 'Tanglefoot', a sticky material that traps any insect venturing onto the trap. Past research has shown that the color purple is attractive to the family *Buprestidae*. Beetles are very visual, not only preferring purple but also are more likely to colonize trees in sunny locations (http://www.emeraldashborer.info/files/developsurveytrap.pdf). According to Dr. Houping Liu (USDA Forest Service, Pers. Communication) although traps will likely be placed in southeast Pennsylvania this spring (2011) they are placed in specific 1.5 mi² grid which may preclude Morris Arboretum's property.

2. Trap Trees

For the same reason that sticky traps are used, ash trees can be made to attract early EAB arrivals in order to monitor numbers. This is done by intentionally stressing or girdling trees. Girdling is accomplished by removing a six to eight inch strip of bark down to the phloem in the summer, disrupting the flow of nutrients made by photosynthetic activity. As stress increases, volatile compounds are emitted and perceived by emerald ash borers. The change in color, that is, light reflecting from the leaves is also said to be attractive to the borers (www.emeraldashborer.info/files/handoutforpdf.pdf).

Because emerald ash borers are arriving from the west and attack open or edge canopy trees, and green ash (Fraxinus pensylvanica) preferentially, a green ash is usually designated as a trap tree. Bark must be stripped to the cambium in order to stress the tree, making it more attractive to emerald ash borers. It would then be felled in the fall and assessed for larval numbers.

APPENDIX E: Plant Clinic Web Page

EMERALD ASH BORER: COMING TO A TREE NEAR YOU

Above: emerald ash borer- a small green beetle from Asia Below: Purple sticky trap used by USDA to monitor

INTRODUCTION: As global trade has increased, more goods are coming in from overseas, sometimes bringing with them accidental cargos of destructive insects and other organisms. Shipments of U.S. food imports from China more than tripled in value between 2001 and 2008 (USDA 2009). Five hundred million plants are imported to the U.S. each year, and about 30 new invasive insects are discovered annually in the U.S., up sharply over the last decade (Maher 2008). An estimated 50,000 plant and animal species have been introduced into the U.S. throughout history, many accidentally (Maher, K. *The Wall Street Journal*, 2010). Without the natural controls present in their native ranges, it is no wonder that some insect populations grow exponentially and ravage their new environment. Just as smallpox decimated indigenous Americans when it was brought from Europe, so the emerald ash borer (EAB) is decimating millions and millions of ash trees in the United States. First introduced in Michigan in the 1990's, the emerald ash borer (EAB), (*Agrilus planipennis* Fairmaire) was identified in 2002. It is believed to have been transported in shipping material from Asia. Devastation in Canada and US has killed more than 50 million trees, causing extensive economic and environmental damage (USDA Forest Service 2010). Closer to home, ash trees make up 3.6% of the 300 million forest trees in Pennsylvania, about 10,800,000 trees. That's a lot of trees. The movement of this deadly insect is being monitored carefully. Interestingly, it seems to move primarily along highways. From this we can deduce that campers and others are taking firewood containing the larvae with them

▲Natural area in Michigan where ALL ash trees were killed by the emerald ash borer. cfs.nrcan.gc.ca/images/9872

from a known infested area to another site where the borer has not yet found its way. Unknowingly a camper may have brought the beetle to a new site as most campers leave unused firewood behind when they leave, firewood that is possibly infested with emerald ash borer. The emerald ash borer has been found in central Pennsylvania as well as eastern New York state and Maryland. We would best be prepared.

LIFE CYCLE: From late May (when black locust trees bloom (at 550 growing degree days), through September, adults from last year's larvae emerge from ash trees through D-shaped holes in the bark. Bright metallic green and only about ½" long, adults live about 3 weeks, feeding on the leaves of nearby ash trees, foliar feeding that in no way hurts the tree. The female lays her eggs on the surface and crevices of ash tree bark. In 2-3 weeks, when the eggs hatch, the larvae begin chewing their way through the outer bark to the phloem, the living, growing portion of the tree, where water and nutrient transport occurs. The larvae live and develop here, making S-shaped tunnels, disrupting tree activities and resting until the next spring when they emerge and the cycle resumes. It takes 2-3 years before noticeable symptoms appear on a tree. At first, the top one-third of the canopy begins to look bare. Water and nutrients are blocked so there can be no growth, no life. The upper canopy is where the insect lives in the early stages making the tiny D-shaped exit holes that are difficult to see. Additionally, no frass (insect debris consisting of woody remnants and waste) is produced that could alert an observer on the ground. Suckers will appear at the base of the tree or anywhere along the trunk as the tree attempts to produce more leaves for photosynthesis. The trunk swells and splits as new wood is put down in an attempt to heal the damaged portions. Woodpecker activity increases as the insects multiply, noticeable in winter, beginning at Thanksgiving. Ash trees die within 2-3 years of infestation.

CONTROL: As of now, there is no cure. Insecticides, injected annually, are effective but expensive long term projects, although this is the best option while research on integrated strategies continues. Biological control (biocontrol) is a better way. It is the best option for cost-effective, long-term EAB population reduction. Scientists have traveled to the insects' homeland, China, to identify natural enemies. Three species of parasitic wasps have been found that can destroy 50 to 90 percent of the ash borer eggs or larvae they encounter (USDA-APHIS 2010). The wasp's young feed on the EAB eggs or larvae, eventually killing them. The USDA has determined that the wasps are not a threat to anything other than ash borers. Whether they will survive cold winters and predation in the US remains to be seen. Meanwhile insecticides can be used to prolong the lives of important ash trees, until biocontrols are known to be effective. Standard insecticides like Imidacloprid, or Emamectin benzoate (TREE Äge) can be applied annually or biennially, respectively.

WHAT IS TO BE DONE?

Ashes are large shade trees; they have been used to replace the elms in cities and towns. Elms replaced the chestnuts, another native North American tree that was destroyed by an introduced fungus. There is 100 percent mortality of all native North American ash trees following EAB infestation. That's 300 million trees in Pennsylvania. The beetle moves by both natural and artificial (human) movement. If an infested tree is found, the entire county must be quarantined. Quarantines prohibit the movement of potentially infested items such as ash limbs, branches, and logs out of affected counties without a permit. Wood cannot leave the quarantined areas without treatment by kiln drying, fumigation, or debarking, including removal of ½ inch of the tissue under the bark.

By far, the principal method of transport for the emerald ash borer has been movement of firewood. Buy local firewood when you arrive at your destination and leave any unused portion behind when you leave. Movement of nursery stock and wood packing materials are the next most often cited reasons for the spread of emerald ash borer.

Wood from ash trees is used for baseball bats, handles of sporting equipment, furniture and basket-making, among other things. If you wonder why baseball bats break more frequently than they used to, it's because they are now more often made from maple, a strong but more brittle wood, compared to ash.

In Pennsylvania, we have the advantage in knowing about the insect and how to identify infestations. Commercials are introducing the public to EAB. So far, it has not been found in the Philadelphia area but it will arrive soon, as it was found in Carlisle, PA in 2010. Keep your eyes

open starting in May when the black locusts bloom. Morris Arboretum's ash collections contain several species of oriental ash that may show some resistance to EAB. Tony Aiello, Director of Horticulture at Morris Arboretum, is actively collecting Asian ash species that may contain resistance that could be bred in into our native American ash trees in the future.

To report possible infested trees in Pennsylvania, contact:
The Pennsylvania Department of Agriculture 1-866-253-7189
1015 Bridge Road, Collegeville, PA 19426, (610) 489-1003

◀EAB is a very small beetle

◀Dead ash struggling to recover using carbohydrate reserves stored in the roots and trunk. It's too late. www2.dnr.cornell.edu

FOR MORE INFORMATION:

Emerald Ash Borer www.emeraldashborer.info
USDA-APHIS (Animal and Plant Health Inspection) www.www.aphis.usda.gov ›
Coalition for Urban Ash Tree Conservation www.emeraldashborer.info/files/conserv.ash.pdf
Pennsylvania Department of Conservation and Natural Resources
Penn State University

References:

Cesa, Ed et al. 2010. "Integrated Program Strategy for Reducing the Adverse Impacts of Emerald Ash Borer Throughout the Northeastern Area." USDA Forest Service, Northeastern Area State and Private Forestry- Forest Health and Economics. Accessed 19 April 2011.

Maher, K. "The Vexing Bugs in the Global Trading System" The Wall Street Journal. 15 Jan 2010. Accessed 10 September 2010. http://www.dcnr.state.pa.us/forestry/fpm_invasives_eab.aspx.

USDA–APHIS/ARS/FS. 2010. Emerald Ash Borer, *Agrilus planipennis* (Fairmaire), Biological Control Release Guidelines. USDA–APHIS–ARS-FS, Riverdale, Maryland. http://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/EAB-FieldRelease-Guidelines.pdf Accessed 19 April 2011.

USDA Economic Research Bulletin 52, July 2009. Imports from China and Food Safety Issues. http://www.usda.ers.gov Accessed 19 April 2011.

by Rebecca Bakker, Urban Forestry Intern, May 2011

APPENDIX F: Guidelines for Cost of Treatment

Accession #	EAB #	2 B Acc. ?	Latin Name	Common Name	*Grid#*	*Meas*	*Cbh 1*	*Cbh 2*	*Dbh 1*	*Dbh 2*	*Total Dbh*	*Rate*	*Cost to treat/ 2 yrs*	*Comments*
32-2411*A			Fraxinus americana	white ash	D17		99		31.5		32	$12/in	$384.00	
54-0607*A			Fraxinus americana	white ash	E19		103		33		33	$12/in	$396.00	
2000-348*C			Fraxinus americana var. biltmoreana	Biltmore ash	G17									To be determined
32-2811*A			Fraxinus pennsylvanica	red ash	B20		95		30		30	$12/in	$360.00	
54-0608*A			Fraxinus pennsylvanica	red ash	D17		105		33		33	$12/in	$396.00	
81-280*A			Fraxinus pennsylvanica	red ash	F20		19	47	3	15	18	$10/in	$180.00	
2001-069*A			Fraxinus texensis	Texas ash	H17									To be determined
												TOTAL	$1,716.00	
			TREE-Äge -$10/inch for trees <20 inches D. Higher for larger trees, up to $16 per diameter inch in jumbo trees (over 40 inch diameter.)											
			Imidacloprid Trees <8 inch diameter may be treated by basal soil drench or ground injection											

APPENDIX G: Thousand Cankers Disease (TCD)

Black walnut (*Juglans nigra*), is one of the largest hardwood trees found in the US, and is valued economically and ecologically for its wood and edible nuts. Native to the deciduous forests of the eastern United States (US), from Massachusetts to Florida and west to Minnesota and Texas, black walnut also occurs naturally in southern Ontario, Canada. Thousand cankers disease, vectored by the walnut twig beetle (WTB), is a lethal insect-fungal pest complex native to western United States and only occurs on walnut species (*Juglans*). It coincides with and is tolerated by the western Arizona walnut (*Juglans major*), as a minority pest. Since the introduction to western landscapes of *Juglans nigra*, an eastern species, dieback and mortality of the eastern species has become severe. Also, preliminary pathogenicity tests have shown that of two other species within the walnut family exposed to TCD, butternut *(Juglans cinerea)* developed cankers but pecan (*Carya illlinoinenesis)* did not. Appendix A, Fig.6 shows the US native range of black walnut in green with known TCD infestations in red. In late July 2010, eastern black walnut trees in Tennessee were found to be infested with TCD and confirmed in four counties near Knoxville. It was the first discovery of this disease within the native range of eastern black walnut. Based on the level of deterioration of the infested trees, experts suspect that TCD has been in Tennessee for several years. However, it is too soon to be certain how this disease may act in the walnut's native range.
(http://www.ohiodnr.com/LinkClick.aspx?fileticket=cHEIm%2FPkNt0%3D&tabid=5320).

Because TCD is not yet a federally quarantined pest, it is up to individual states to make decisions to restrict movement of black walnut wood. Tennessee along with others states, has a TCD quarantine. However, as a valuable hardwood, oversight is difficult. Today, most actions plans consider rapid detection and removal of infected trees as the primary means of control.
NB: The portion of this readiness plan that relates to thousand cankers disease consists of mapping *Juglans* spp. on Morris Arboretum grounds only. The management plan itself remains to be completed as a modified form of the EAB Readiness Plan when appropriate.

The following spreadsheet lists all black walnuts (*Juglans nigra*) found on Morris Arboretum property. See CAD file for map.

Accession #	TCD #	AB #	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*
2001-079A			Juglans nigra	black walnut	J4		98					
2006-078*A			Juglans nigra	black walnut	N12		71					no tag
2010-057A			Juglans nigra	black walnut	J4		83					
32-2050*A			Juglans nigra	black walnut	F20		49					
32-2407*A			Juglans nigra	black walnut	A18		105					
53-176A			Juglans major	Arizona black walnut	J16							
54-0090*A			Juglans nigra	black walnut	K21		71					
54-1432B			Juglans nigra 'Laciniata'	cutleaf black walnut	Q4		0					removed
60-275*A			Juglans nigra	black walnut	K21		84					
60-276*A			Juglans sp.	walnut	K21							
82-073A			Juglans nigra	black walnut	F9		103					lg. basal cavity N side
82-116A			Juglans nigra	black walnut	J3		86					
82-116B			Juglans nigra	black walnut	J3		75					double lead: 1 gone, hollow base
82-116C			Juglans nigra	black walnut	J3		92					mechanical wound lower trunk
82-116D			Juglans nigra	black walnut	J3		91					groundhog hole at base
82-204A			Juglans		J9							
	33	33	Juglans sp.	walnut	H11		44					AB Project #
	36	36	Juglans sp.	walnut	H11		57					AB Project #
	45	45	Juglans sp.	walnut	G11							AB Project #
	46	46	Juglans sp.	walnut	G11		38					AB Project #
	47	47	Juglans sp.	walnut	G11		36	36	37	42	34	AB Project #
	54	54	Juglans sp.	walnut	G11		21					AB Project #
	59	59	Juglans sp.	walnut	G11		21					AB Project #
	61	61	Juglans sp.	walnut	G11		47					AB Project #
	79	79	Juglans sp.	walnut	G11		71					AB Project #
	178	178	Juglans sp.	walnut	G12		24					AB Project #
	182	182	Juglans sp.	walnut	G12		??					AB Project #
	184	184	Juglans sp.	walnut	G12		73					AB Project #

Accession #	TCD #	AB #	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*
	191	191	Juglans sp.	walnut	G12		73					AB Project #
	195	195	Juglans sp.	walnut	G12		37					AB Project #
	1426	317	Juglans sp.	walnut	H9		27					AB Project #
	1425	328	Juglans sp.	walnut	H9		36					AB Project #
	1424	332	Juglans sp.	walnut	H9		47					AB Project #
	1427	364	Juglans sp.	walnut	G9		40					AB Project #
	1428	367	Juglans sp.	walnut	G9		28					AB Project #
	1423	379	Juglans sp.	walnut	G9		65					AB Project #
	1421	384	Juglans sp.	walnut	G9		20					AB Project #
	1401		Juglans sp.	walnut	H1		27					
	1402		Juglans sp.	walnut								removed
	1403		Juglans sp.	walnut	F3							removed
	1404		Juglans sp.	walnut	E4		130					at mill
	1405		Juglans sp.	walnut	E4		74					
	1406		Juglans sp.	walnut	E5		44					
	1407		Juglans sp.	walnut	E5		38					inaccessible: no tag applied
	1408		Juglans sp.	walnut			44					
	1409		Juglans sp.	walnut	E6		43					
	1410		Juglans sp.	walnut	E6		54					
	1411		Juglans sp.	walnut	E6		50					
	1412		Juglans sp.	walnut	E7		39					
	1413		Juglans sp.	walnut	E7		37	34				
	1414		Juglans sp.	walnut	F6		35					
	1415		Juglans sp.	walnut	E8		60					
	1416		Juglans sp.	walnut	E8		47					
	1417		Juglans sp.	walnut	E8		32					
	1418		Juglans sp.	walnut	E9		30					
	1419		Juglans sp.	walnut	E9		40					
	1420		Juglans sp.	walnut	E6		54					
	1422		Juglans sp.	walnut	G9		20					

Accession #	TCD #	AB #	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*
	1429		Juglans sp.	walnut	G11		15					
	1430		Juglans sp.	walnut	G11		20					
	1431		Juglans sp.	walnut	G11		19					
	1432		Juglans sp.	walnut	G11		40					
	1433		Juglans sp.	walnut	G11		17					
	1434		Juglans sp.	walnut	G11		29					
	1435		Juglans sp.	walnut	G11		25					
	1436		Juglans sp.	walnut	G11		25					
	1437		Juglans sp.	walnut	G11		32					
	1438		Juglans sp.	walnut	G11		23					
	1439		Juglans sp.	walnut	G11		36	44				
	1440		Juglans sp.	walnut	G11		44	50				Danger: metal bar between boles
	1441		Juglans sp.	walnut	G11		32	35	39			
	1442		Juglans sp.	walnut	G11		11	23				
	1443		Juglans sp.	walnut	F11		25					
	1444		Juglans sp.	walnut			47					
	1445		Juglans sp.	walnut	F17		100					
	1446		Juglans sp.	walnut	F17		79					
	1447		Juglans sp.	walnut	F17		26					
	1448		Juglans sp.	walnut			42					
	1449		Juglans sp.	walnut	E10							
	1450		Juglans sp.	walnut	E10							
	1451		Juglans sp.	walnut	E10		32					
	1452		Juglans sp.	walnut	E10		28					
	1453		Juglans sp.	walnut	F10		36	26	40			
	1454		Juglans sp.	walnut	F10		23	31	23			
	1455		Juglans sp.	walnut	F10		21	29				
	1456		Juglans sp.	walnut	E10		35					suspended over creek
	1457		Juglans sp.	walnut	F10		26	24	27			yellow ribbon
	1458		Juglans sp.	walnut	F10		18					
	1459		Juglans sp.	walnut	F10		22	22	17	8		yellow ribbon
	1460		Juglans sp.	walnut	F10		21	18	20			
	1461		Juglans sp.	walnut	F11		15					
	1462		Juglans sp.	walnut	F11		20	15	16			
	1463		Juglans sp.	walnut	F11		85					
	1464		Juglans sp.	walnut	F11		60					
	1465		Juglans sp.	walnut	F11		20					

Accession #	TCD #	AB #	Latin Name	Common Name	*Grid#*	*Meas*	*cbh 1*	*cbh 2*	*cbh 3*	*cbh 4*	*cbh 5*	*Comments*
	1466		Juglans sp.	walnut	G12		28					
	1467		Juglans sp.	walnut	F11		14					
	1468		Juglans sp.	walnut	F11		22					
	1469		Juglans sp.	walnut	F11		27					
	1470		Juglans sp.	walnut	F11		30	20	34			
	1471		Juglans sp.	walnut	F11		25					
	1472		Juglans sp.	walnut	F11		27	15	25	24		
	1473		Juglans sp.	walnut	F11		18					
	1474		Juglans sp.	walnut	F11		19					
	1475		Juglans sp.	walnut	F11		26					
	1476		Juglans sp.	walnut	G12		24	25				
	1477		Juglans sp.	walnut	G12		36	21				
	1478		Juglans sp.	walnut	G11		35	36				
	1479		Juglans sp.	walnut	G11		20					
	1480		Juglans sp.	walnut	G11		24					
	1481		Juglans sp.	walnut	G11		15	26				
	1482		Juglans sp.	walnut	G11		35					
	1483		Juglans sp.	walnut	G11		23					
	1484		Juglans sp.	walnut	G11		17					
	1485		Juglans sp.	walnut	G11		12					lower trunk scar/canker
	1486											tag not used
	1487		Juglans sp.	walnut	G11		17					
	1488		Juglans sp.	walnut	G12		24					middle of path, red ribbon
	1489		Juglans sp.	walnut	H11		11					
	1490		Juglans sp.	walnut	H12		52					
	1491											tag not used
	1492		Juglans sp.	walnut	H12		70					
	1493		Juglans sp.	walnut	H12		88					
	1494		Juglans sp.	walnut	H12		15					
	1495		Juglans sp.	walnut	G14		72					
	1496		Juglans sp.	walnut	G13		24	23				meas. 2'
	1497		Juglans sp.	walnut	G13		23					
	1498		Juglans sp.	walnut	G13		27					
	1499		Juglans sp.	walnut	H14		21					
	1591		Juglans sp.	walnut	H14		16					
	1592		Juglans sp.	walnut	J13		55					hollow base
	1993		Juglans sp.	walnut	J13		96	57	84			mystery species: *Juglans regia* ?

TITLE: **MANAGING THE HEALTH OF HEMLOCKS AT THE MORRIS ARBORETUM**

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DATE: **April 2011**

ABSTRACT:

Adelges tsuga (Homoptera: Adelgidae), hemlock woolly adelgid (HWA), is an invasive insect pest from Asia that has been affecting the health of native hemlocks, *Tsuga canadensis* and *T. caroliniana*, in the northeast since 1951 in both natural and landscape settings. HWA is the most destructive pests of hemlocks in our area. The first report of HWA at the Morris Arboretum was in the late 1970s, when it appeared sporadically throughout the living collection on *T. canadensis* and *T. carolinana*.

The hemlock collection is an important component of the Morris Arboretum due to its role in the landscape and the tradition of plant exploration. The collection consists of wild-collected material from North America, *T. canadensis* and *T. caroliniana*, and Asia, *T. chinensis*, *T. diversifolia*, and *T. sieboldii*. An evaluation of hemlock health was performed based on tree appearance and presence of pest populations. The HWA life cycle was studied and monitored to determine the best time to control the population. A treatment plan was established and carried out in the fall of 2010 using appropriate control methods. The efficacy of the treatment methods was assessed and the results were used to determine the safest and most effective control for the future management of hemlocks at the Morris Arboretum.

The future management recommendations are based on the results of the project and describe an integrated approach; relying on monitoring, mechanical controls, targeted use of chemical controls, and thorough record keeping to maintain tree health. Within a controlled landscape HWA and other hemlock pests can be controlled to manageable population levels.

Managing the Health of Hemlocks at Morris Arboretum

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BACKGROUND INFORMATION

Tsuga canadensis, eastern hemlock, is an important forest component, growing in almost 19 million acres of northeastern and Appalachian forests (McWilliams and Schmidt 1996), extending from Nova Scotia to Alabama and west to Minnesota. It is a large tree with the potential to reach 140 feet, 3 to 4 feet in diameter and live for 300 to 400 years or more. Hemlocks are commonly restricted to cool, humid climates with adequate moisture, acidic soils, and good drainage, although they can be found growing on drier soils on slopes and ridge tops. *T. canadensis* is extremely shade tolerant, growing in the understory with as little as 5 percent full sunlight (Godman and Lancaster 1990). In northeastern forests, hemlocks are found growing with diverse deciduous trees or in relatively pure stands. In Pennsylvania, eastern hemlock is the state tree growing throughout much of the state. In southern parts of the state hemlock occurs on steep, north-or-east facing slopes along streams. In the northern parts it often occurs in pure stands in moist ravines, stream valleys, and wooded swamps (Rhoads and Block 2005). *T. caroliniana* is limited to the Blue Ridge Mountains of the Southern Appalachians. It is a smaller tree reaching 45 to 60 feet tall.

Mature hemlock forests form a dense evergreen canopy that creates unique environmental conditions critical to terrestrial and aquatic ecosystems. The canopy provides protection from cold winter winds and shade on hot summer days, helping wildlife to save energy. The trees also provide nesting and roosting sites for birds. Some animals that utilize the benefits of hemlock forests include deer, porcupine, snowshoe hare, rabbit, turkey, black-throated-green warbler, rough grouse, blackburnian warbler, acadian flycatcher, solitary vireo, northern goshawk, and aquatics. Hemlock stands are important for stream quality, regulating characteristics such as temperature and stream flow. Hemlock forest-cover along a stream can reduce water temperatures by as much as 4°C (Overton et al. 2010). This unique and irreplaceable quality provides cold pockets for brook trout and macroinvertebrates including mayflies, stoneflies, caddisflies, and salamanders that thrive in cool temperatures.

Hemlocks are beautiful trees, adding charismatic features to the landscape. At the Morris Arboretum the weeping hemlock, *T. canadensis* 'pendula' adds to the serene essence created by the swan pond. A grouping of *T. canadensis* by the log cabin provides shade for visitors on a hot August day and an attractive site for birders. There are 274 named cultivars, making hemlock one of the most cultivated landscape trees in the United States (McClure et. al 1996).

Adelges tsuga (Homoptera: Adelgidae), hemlock woolly adelgid (HWA), is a small aphid-like insect. It feeds by inserting its long hollow sucking mouthparts deep into the base of the hemlock needles. It depletes starch reserves by ingesting the nutrients in the ray parenchyma cells. In response, the tree blocks off the wound created by the insect. This disrupts the flow of nutrients between the twig and its needles, eventually leading to reduced vigor and death of the tree. The decline and eventual death of a hemlock tree following initial infestation may occur within 2 to 12 years. All ages and sizes of trees are susceptible. Stress factors that affect the rate of decline include drought, poor site conditions, and other insect and disease pests such as

elongate hemlock scale (EHS) and spruce spider mite, both of which are present at the Arboretum.

The first report of HWA in northeastern North America was in Richmond, Virginia in 1951 in a private plant collection. It was discovered in southeastern Pennsylvania in 1969, and quickly became a serious pest in both forest and landscape settings. Scientists have discovered a direct link between HWA in eastern North America and southern Japan. The insect appears to have arrived on nursery stock (Havill and Montgomery 2008). HWA is not a severe pest in its native range because of abundant and effective natural predators that reduce infestation levels.

Today, the infestation of HWA in the eastern United States ranges from northeastern Georgia to Southern Maine and westward to eastern Tennessee. Populations of HWA have been expanding rapidly throughout the natural range of hemlock at an estimated rate of 20 to 30 km per year (McClure et al. 1996). Vectors include wind, wildlife, humans, and transport on infested nursery stock.

Some limitations to HWA survivorship exist. Natural mortality of North American populations is found to be 37.3 to 68.7 percent annually (McClure et al. 1996). Very cold temperatures reduce population size. A case study in Connecticut showed that after a temperature of -5°F HWA population declined by 90 percent. Optimizing hemlock growing conditions is showing significance in the management of pest levels. Yet HWA is adapting and being protected by snow coverage. It is anticipated that as hemlock mortality continues, stands will be replaced by deciduous species that will have ecological impacts on terrestrial and aquatic ecosystems.

MATERIALS AND METHODS

To manage the health of hemlocks at the Morris Arboretum 70 trees were chosen for monitoring, treatment, or to act as controls. Fifty-five (55) high priority trees were the treatment group and 15 low priority trees comprised the control group. All 70 trees were monitored to observe adelgid development, population levels, and tree appearance. The results of comparing treated trees to non treated trees, post-treatment, established a baseline for evaluating the efficacy of treatments. Also, information was collected pretreatment on HWA population levels to be compared to post treatment HWA population levels. It was not possible to actually make this comparison because the treatment uptake time exceeds the time limit of my project. All information is recorded for future use.

In September each tree was evaluated for population density of hemlock pests (HWA, EHS and mites) and tree appearance (needle color, canopy density, and new shoot growth). HWA was evaluated by counting the number of adelgid on a 10 inch branch containing current year's growth up to 10 individual adelgids, this is repeated 10 times for each tree. This resulted in a maximum possible value of 100 adelgids per tree sample, or 100 percent infestation (Cowles 2010). HWA and EHS were recorded as a level of pest population: absent, light, moderate, or heavy. Absent, when no individuals were found, light when population was 1-20 percent,

moderate when population was 21-60 percent, and heavy when population was 61-100 percent. After evaluation and consultation with local experts the following treatment options were selected: Safari, Merit, Safari and horticultural oil or Merit and horticultural oil. Horticultural oil and the systemic insecticides, Merit and Safari, have varying specifications for targeted pest, ecological impact, uptake, and residual time.

In October the targeted treatments were conducted following the *Morris Arboretum of the University of Pennsylvania Policy on Pest Management and Pesticide Use* and *Material Safety Data Sheets* for specified chemicals. The treatment took a total of three days to complete. The even distribution of the chemical throughout the tree, or at the tree base during application, aids in equal absorption and best results. In the following winter months HWA was reevaluated on treated and non treated hemlocks using the method described above.

As another means of tree health evaluation, pictures were taken upward through the canopy of hemlock stands using a wide angle lens. Gap Light Analyzer (GLA) software was employed to analyze canopy structure and calculate light penetration or percentage of canopy openness. The assumption is that canopy openness and light penetration are directly correlated with needle loss and canopy degradation due to HWA. Three stands: the log cabin, Widener woods and Meadowbrook Avenue, represented hemlock canopies that have been threatened by HWA. The canopy at Pastorius Park represents hemlocks free of HWA. These trees have received ongoing treatment since 1998 and have been free of HWA for several years.

RESULTS AND DISCUSSION

Hemlock woolly adelgid population levels of the treatment and control group were compared to determine treatment efficacy. HWA population levels were significantly lower among the treatment group compared to the control group as seen in Figure 1. The median of the control group was 93 percent infested, the median of the treatment group was 5 percent infested. Within the treatment group the range between minimum and maximum populations is 0 percent to 22 percent, a fairly narrow range. The higher end of the treatment group represents the results of Merit while the lower range was Safari. Over an extended period of time a greater difference among the treatment types would be expected due to varying chemical specifications such as absorption rates and residual time. Safari would be expected to show almost immediate decline in pest populations. Over a longer period of time Safari would soon provide less protection from infestation. Merit would be expected to show a slower yet steady and more persistent decline of infestation levels. A larger sample size and random assignment of treatments might have produced a wider range of results.

The Gap Light Analyzer (GLA) provided data on canopy density at four sites. Canopy density is greatest at Pastorius Park allowing less light penetration compared to trees at the other three sites that are currently infested with HWA and have been for years, as seen in Figure 2. Arborist working at Pastorius Park informed that the hemlocks there had been free of HWA for over five years. There is great significance in the density of hemlock canopies especially when considering its ecological role to terrestrial and aquatic ecosystems.

The HWA population levels on species of hemlock vary according to their geographic origin. Chinese species *T. chinensis* and Japanese species *T. divesifolia* show resistance to HWA. Native species, *T. canadensis* and *T. caroliniana,* and Japanese species, T. *sieboldii* show susceptibility as seen in Figure 3.

See Appendix for Result Figures and Data.

CONCLUSION AND MANAGEMENT RECOMMENDATIONS

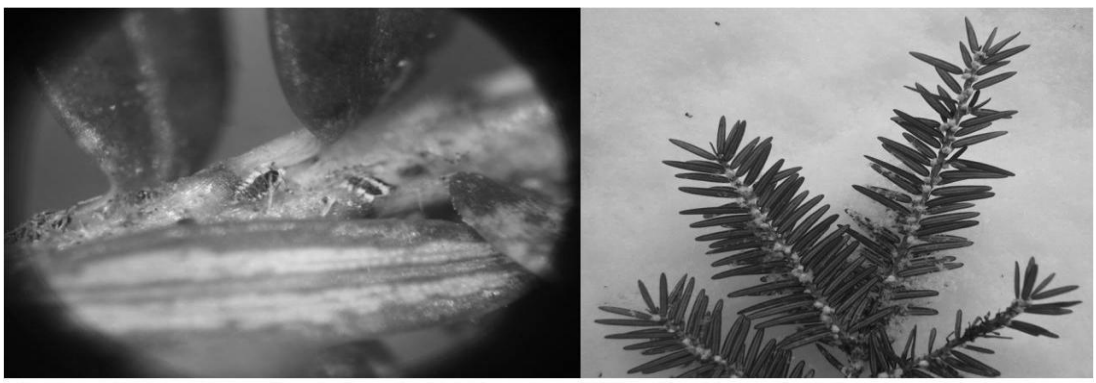
At the Morris Arboretum, North American species: *T. canadensis* and *T. caroliniana* show the greatest susceptibility to hemlock woolly adelgid while most Asian species show high resistance. If native *Tsuga* species are to remain a part of the Morris Arboretum living collection, it is imperative to manage level of pests, especially HWA. This can be accomplished by scouting to monitor health and the targeted use of chemical controls.

The hemlock pest scouting form, stored on the shared drive S:\Morris\General\NoBackUps\IPM\HemlockRecord.xlsx, can be used yearly to record and communicate information on pests and treatment status. Treatment options have variable absorption, residual timing, and environmental impacts. All of which need to be considered while choosing the treatment method. Also keep in mind that alternating treatment chemicals may become necessary if pests develop a resistance.

Scouting and Evaluating

The *Hemlock Pest Scouting Form* can be used yearly to record and communicate information on pests and treatment status. Data should include identification of present pests, pest population levels, and tree appearance; reflecting needle color, canopy density, and shoot growth. This data will be used to understand the health of the tree and to make further decisions about chemical or manual control. Monitoring is most effective when conducted periodically throughout the year. When scouting for HWA in the fall a hand lens is required to see the small sistens at the base of the current year's needle. In the winter or early spring white woolly masses are easily visible. These identifications are depicted in the image below.

Cultural Practice



(Left image) Sistens at base of hemlock needle, (right image) adult HWA with white woolly ovasic

Studies completed by Longwood Gardens, Nathan Havil and others have shown improved hemlock health by reducing invasion of HWA and improving growing conditions. Reducing infestation can be done by selecting appropriate trees and branches for removal to decrease the inoculum of HWA. While transporting infested material, caution needs to be taken to avoid further dispersal of HWA, this is especially important in March while the HWA is in the crawler stage. Also, avoid intentionally attracting wildlife into hemlock trees. Avoid placing bird feeders in or near hemlock trees to decrease dispersal via birds.

Improve growing conditions by ensuring 1 inch of water/per week within the drip line of the tree (this includes rainfall), removing dead wood, providing organic matter greater than 4 percent, avoiding nitrogen fertilization, maintaining soil pH between 4 to 5, and reducing soil compaction.

T. chinensis and *T. diversifolia* are highly resistant and suitable to conditions at the Arboretum. The planting of these trees is encouraged while research and improvements are made to overcome HWA. It is also encouraged to be alert for resistance within wild collections and varieties of native plants.

Planning Chemical Treatment

Chemical control is an essential component in using an IPM approach to reduce and control the population of hemlock pests including HWA. Chemicals should be used only in the response of an infestation. Trees should be prioritized to maintain a manageable pest level, appropriate cost, and overall best management practice.

Treatment options have variable absorption, residual timing, and environmental impacts. All of which need to be considered while choosing the treatment method. Alternating treatment chemicals may become necessary if pests develop a resistance.

Table 1: Treatment Option Information						
Product	**Product application**	**Target Hemlock Pest**	**Time for Uptake**	**Residual**	**Environmental and Human Impacts**	**Cost**
Safari (Dinotefuran)	Systemic insecticide, soil drench	HWA, EHS	3-6 weeks	Up to 2 years	Water soluble, greater water quality impacts, highly toxic to bees	$$
Merit (Imidacloprid)	Systemic insecticide, soil drench	HWA	1-12 months	Up to 7-8 years	Low mammalian toxicity	$
Horticultural Oil (Petroleum Oil)	Foliar spray	HWA, EHS mites	On contact, "suffocation"	none	Relatively safe to applicator, beneficial insects and environment, toxic to fish	$

Timing is very important in the control of hemlock pests. Typically horticultural oil should be applied twice each year in early spring and late fall to target each generation. The amount and concentration should be one percent mixture in the spring and two percent mixture in the fall. It is found to be most effective when used in the spring, directly after 100 percent egg hatch, estimated to occur in our region between 505 and 676 GDD using Base50. Refer to life cycle in Appendix.

Continuous record keeping is very important. Each year records are to be entered into an Excel spread sheet named HemlockRecord.xlsx document, found in the shared drive: S:\Morris\General\NoBackUps\IPM\HemlockRecord.xlsx

See Appendix for detailed information on identification, treatment options and spread sheet.

LITERATURE CITED

Cowles, Richard, The Connecticut Agricultural Experiment Station, 153 Cook Hill Road Windsor, CT 06095-2010. Personal Communication.

Dalusky, Mark. 2011. University of Georgia. Personal Communication.

Dalusky, M. 2010. Using Imidicloprid & Dinotefuran for Control of Hemlock Woolly Adelgid. UGA Forest Entomology.

Godman, R. M. and K. Lancaster. 1990. Eastern Hemlock. USDA Forest Service

Havill, N. P. and M. E. Montgomery. 2008. The Role of Arboreta in Studying the Evolution of Host Resistance to the Hemlock Woolly Adelgid. Arnoldia 65(3): 2-9

McCLure, M., S. M. Salom and K. S. Shields. 1996. Introduced Pest: Hemlock Woolly Adelgid. Forest Health Technology Enterprise Team., Morgantown, West Virginia.

Onken, Brad. 2011. United States Forest Service. Personal Communication.

Overton, B., A. Kutay, J. Starr, T. K. Beerley, and L. Ochrieter. 2010. Saving Hemlocks, Pennsylvania's Economy, and Our Hunting and Fishing Tradition. The Hemlock 3(4):4-5

Rhoads, A. F. and T. A. Block. 2005. Trees of Pennsylvania. University of Pennsylvania Press., Philadelphia, PA.

Salom, M. S., L. T. Kok, A. Lamb, C. Jubb and B. Onken. 2008. Biological Control of Hemlock Woolly Adelgid: What Is It Going To Take To Make It Work? Forth Symposium on Hemlock Woolly Adelgid in the Eastern United States. Forest Health Technology Enterprise Team., Morgantown, West Virginia.

Schmidt, T.L. and W.H. McWilliams. 1996. Status of Eastern Hemlock in the Northern U.S. In: Ward, J., M. Montgomery, C. Cheah, B. Onken and R. S. Cowles. 2004. Eastern Hemlock Forests: Guidelines to Minimize the Impacts of Hemlock Woolly Adelgid. USDA Forest Service.

Sclar, Casey. 2011. Longwood Gardens. Personal Communication.

Ward, J., M. Montgomery, C. Cheah, B. Onken and R. S. Cowles. 2004. Eastern Hemlock Forests: Guidelines to Minimize the Impacts of Hemlock Woolly Adelgid. USDA Forest Service.

APPENDIX A: Treatment Details

The following paragraphs provide detailed information on the treatment for the control of hemlock pests at the Morris Arboretum.

Imidicloprid-Merit

Merit is a systemic insecticide; its active ingredient is imidicloprid. Merit targets HWA and other sucking insects, it does not control spider mite or EHS. It is applied as soil injections and is actively transported into the tree through the roots. When the chemical reaches the feeding site of the adelgid it paralyzes and kills the pest. Merit works best when applied in the fall or spring, in moist soil and cool air temperatures. Merit takes 6 weeks to 12 months or longer to become effective. Control of HWA on new shoot growth may be seen within a few years, residual time is 7 to 8 years (Dalusky 2010). Residual time is based on observations made by US Forest Service, Forest Entomologist at University of Georgia and other sources. It is convoluted to quantify a residual time for any treatment because of several factors including the rebound time for HWA to reestablish, winter weather and unknown natural pressures facing HWA recovery. An unresolved issue with Merit is unequal absorption of the chemical throughout the tree, causing the effect to be spotty throughout the canopy. This can be minimized by administering the chemical equally at several around the trunk at a depth of 6 inches below the soil surface.

Dinotefuran-Safari

Safari is a systemic insecticide; its active ingredient is dinotefuran. It targets HWA, EHS, and spider mites. It is applied as a soil drench. It is more water soluble then Merit and moves more quickly through the tree, within 3 to 6 weeks; its residual is approximately 2 years. However, Safari is more expensive and has greater potential to affect water quality of near-by streams (Dalusky 2010). Safari is found to work best when rapid control is needed, such as when trees have no new shoot growth, significant needle loss, badly thinning canopy, and/or dead lower branches.

Horticultural Oil

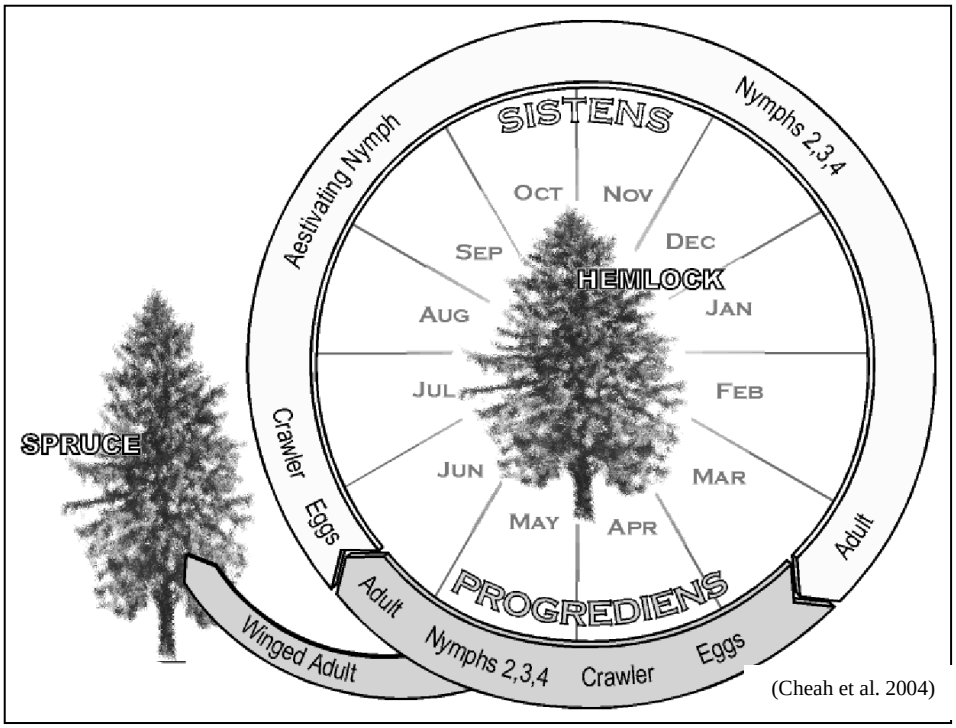
Horticultural oil is a foliar spray, smothering and killing insects on contact. A miticide is sometimes added to reduce the possibility of an increase in mite populations after treatment of HWA.

Biological Control

Predators for HWA are a target of several biocontrol programs in the eastern United States. Progress is being made with rearing *Pseudoscymnus tsugae* Sasaji and three Scymnus sp. In Trenton, New Jersey the Phillip Alampi Beneficial Insect Rearing Lab is known for high quality work and the pursuit of difficult tasks. Currently a small team of dedicated scientists are working to rear *Laricobius nigrinus* (Coleoptera: Derodontidae), a beetle predator of HWA. Native to Ohio, this strain is cold hardy, unlike other *L. nigrinus* that have been reared and released in New Jersey and Virginia. *L. nigrinus* has a narrow host range and has been cleared for field release by USDA APHIS and NAPPO in 2000; they have been released at 22 sites in 8 states. Phillip Alampi Lab continues to test new species and strains to ultimately build a matrix

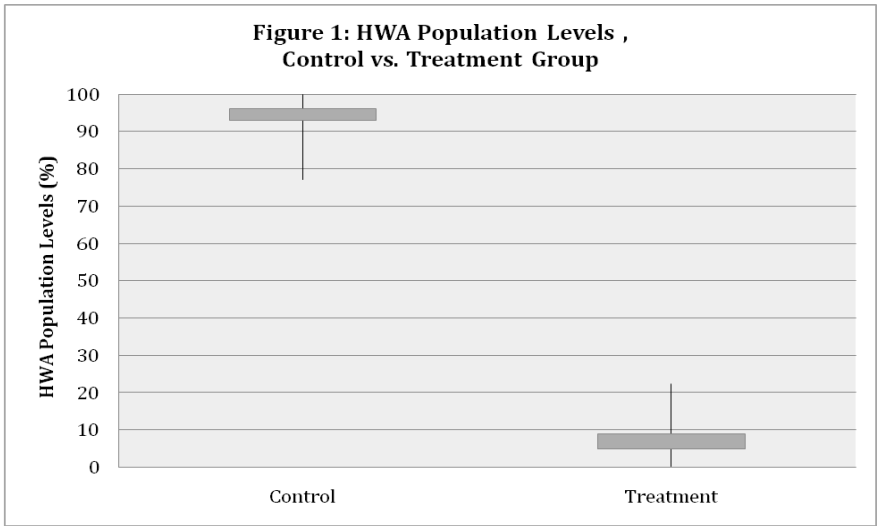
of natural enemies that will contribute to the suppression of HWA. Beneficials are currently not a reliable source of control for the Morris Arboretum hemlocks because of multiple factors including cost, availability, and use of chemical controls. With more research and funding this option may become more available and manageable.

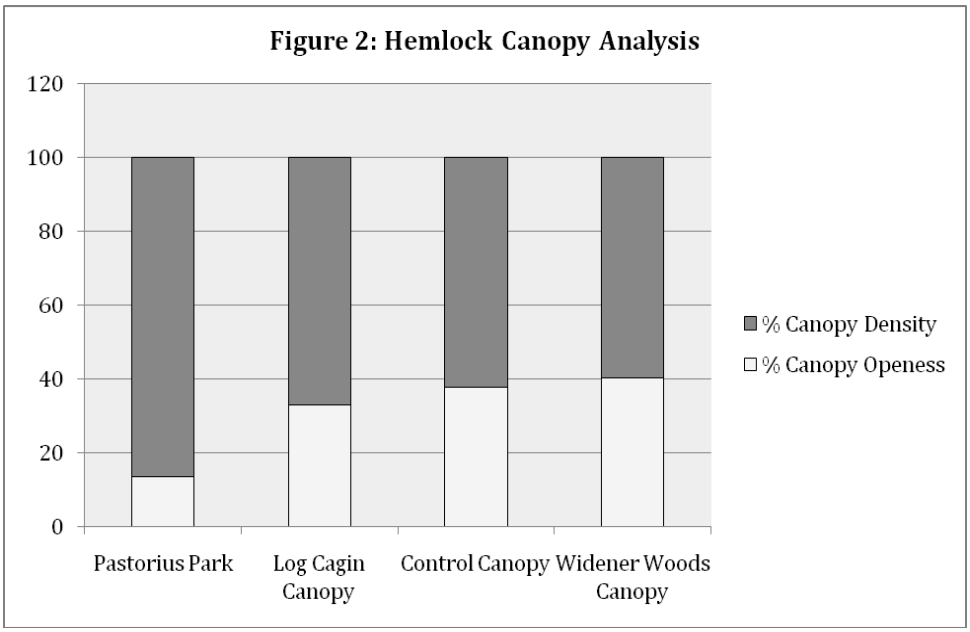
APPENDIX B: HWA Life Cycle as a Guide to Treatment Timing

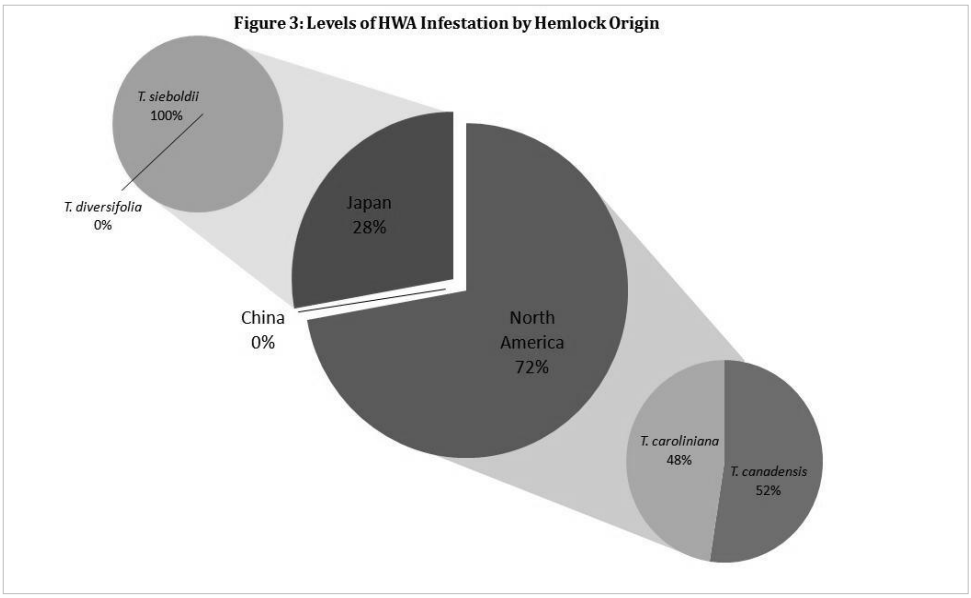


The image above depicts HWA life cycle in Georgia, eastern Pennsylvania zone is cooler and cycle is expected to be shifted slightly clockwise. Highly suggested foliar spray time is after 100 percent egg hatch in spring, estimated to occur between 505-675 GDD.

APPENDIX C: Result Figures







Oct 2010														Jan 2011			
Tree Type	Location	Accession #	Priority	HWA	EHS	Mites Present	Appearance	DBH (inches)	Treated(Y or N)	Date	Product/Method	Product/Method	Observation:	HWA			
Tsuga canadensis	G5	2000-393*A	high	moderate	moderate	no	good	13.38583	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		moderate			
Tsuga canadensis	G5	2000-394*A	high	moderate	moderate	no	good	17.42126	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		moderate			
Tsuga canadensis	J6	2002-203*A	high	heavy	moderate	no	good	20.96457	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga canadensis f. pendula	G21	32-0672*A	high	absent	light	no	good	29.52756	yes	Oct-10		safari/soil injection		absent			
Tsuga canadensis 'Albospica'	G22	32-0673*A	high	moderate	moderate	no	good	35.43307	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			
Tsuga diversifolia	G22	32-0674*A	high	absent	light	no	poor	23.22835	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			
Tsuga canadensis	J19	32-0774*A	high	moderate	moderate	no	good	36.22047	yes	Oct-10		safari/soil injection	Tree too tall to reach with spray hose	moderate			
Tsuga canadensis	H19	32-0775*A	high	moderate	moderate	no	good	50	yes	Oct-10		safari/soil injection	Tree too tall to reach with spray hose	light			
Tsuga canadensis f. pendula	L19	32-1044*A	high	absent	absent	no	good	22.6378	no					absent			
Tsuga sieboldii	E21	32-1499*A	high	moderate	moderate	no	poor	30.70866	yes	Oct-10		safari/soil injection		absent			
Tsuga sieboldii	B20	32-1731*A	high	moderate	moderate	no	poor	21.85039	yes	Oct-10		safari/soil injection		heavy			
Tsuga canadensis	J20	35-6124*EE	high	heavy	light	no	poor	25.98425	yes	Oct-10		merit/soil injection	Tree too tall to reach with spray hose	absent			
Tsuga canadensis	J20	35-6124*KK	high	heavy	light	no	poor	22.14567	yes	Oct-10		merit/soil injection	Tree too tall to reach with spray hose	absent			
Tsuga canadensis 'Bristol's Shortleaf'	J7	35-6504*A	high	moderate	heavy	no	good	20.47244	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		absent			
Tsuga canadensis 'Bristol's Shortleaf'	G18	35-6504*B	high	moderate	light	no	good	19.29134	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga diversifolia	E21	35-6510*A	high	absent	absent	no	good	15.35433	yes	Oct-10		merit/soil injection		absent			
Tsuga canadensis 'Macrophylla'	H18	39-8509*A	high	moderate	moderate	no	poor	32.28347	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		moderate			
Tsuga canadensis	H19	39-8510*A	high	moderate	moderate	no	good	27.55906	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			

Tree Type	Location	Accession #	Priority	HWA	EHS	Mites Present	Appearance	DBH (inches)	Treated(Y or N)	Date	Product/Method	Product/Method	Observation:	HWA			
Tsuga sieboldii	H21	44-059*A	high	moderate	moderate	no	good	24.40945	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga canadensis	H19	45-128*A	high	moderate	moderate	no	good	37.40158	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		absent			
Tsuga canadensis	H19	45-129*A	high	heavy	moderate	no	good	27.55906	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga canadensis	H19	45-131*A	high	heavy	moderate	no	good	38.97638	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		moderate			
Tsuga canadensis	F20	48-823*A	high	heavy	moderate	no	poor	25.59.055	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	light			
Tsuga canadensis	F20	48-823*C	high	moderate	light	no	poor	20.86614	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	light			
Tsuga canadensis	F20	48-823*D	high	moderate	light	no	poor	18.50394	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	absent			
Tsuga canadensis	F20	48-823*E	high	moderate	light	no	poor	21.25984	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	light			
Tsuga canadensis	F20	48-823*G	high	moderate	light	no	poor	13.77953	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	moderate			
Tsuga canadensis	F20	48-823*H	high	heavy	moderate	no	poor	15.35433	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection	Tree by log cabin close to stream, do not use Safari; caution with spray drift	light			

Tree Type	Location	Accession #	Priority	HWA	EHS	Mites Present	Appearance	DBH (inches)	Treated(Y or N)	Date	Product/Method	Product/Method	Observation:	HWA			
Tsuga chinensis	D21	48-883*A	high	absent	light	no	good	21.45669	yes	Oct-10		merit/soil injection		absent			
Tsuga canadensis 'Saratoga Broom'	H20	49-499*A	high	light	absent	no	good	18.11024	yes	Oct-10		merit/soil injection		moderate			
Tsuga canadensis	F20	54-0645*A	high	moderate	light	no	poor	22.44095	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga canadensis	F19	54-0645*B	high	moderate	light	no	poor	17.32284	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga diversifolia	G18	54-0894*A	high	absent	light	no	good	27.75591	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			
Tsuga canadensis var.	J6	75-118*A	high	moderate	light	no	good	21.85039	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga sieboldii	J7	75-126*A	high	absent	light	no	good	22.6378	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			
Tsuga canadensis 'Macrophylla'	E20	78-059*A	high	moderate	moderate	no	poor	15.15748	yes	Oct-10		safari/soil injection		absent			
Tsuga chinensis var. formosana	F22	81-283*A	high	absent	light	no	good	11.7126	yes	Oct-10		safari/soil injection		absent			
Tsuga chinensis var. formosana	F22	81-284*A	high	absent	light	no	good	13.38583	yes	Oct-10		safari/soil injection		absent			
Tsuga chinensis var. formosana	F22	81-285*A	high	absent	light	no	good	15.74803	yes	Oct-10		safari/soil injection		absent			
Tsuga canadensis	F5	82-098*A	high	moderate	light	no	good	27.46063	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		light			
Tsuga caroliniana	H18	94-101*A	high	moderate	light	no	poor	10.5315	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		absent			
Tsuga caroliniana	H17	94-102*A	high	moderate	moderate	no	poor	9.64567	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-017*A	high	heavy	moderate	no	poor	8.956693	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		moderate			
Tsuga canadensis	H16	97-019*A	high	moderate	moderate	no	poor	9.448819	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-020*A	high	moderate	heavy	no	poor	13.18898	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-021*A	high	moderate	moderate	no	poor	10.23655	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-022*A	high	light	moderate	no	poor	12.5	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		absent			
Tsuga canadensis	H16	97-023*A	high	heavy	light	no	poor	7.874016	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		absent			

Tree Type	Location	Accession #	Priority	HWA	EHS	Mites Present	Appearance	DBH (inches)	Treated(Y or N)	Date	Product/Method	Product/Method	Observation:	HWA			
Tsuga canadensis	H16	97-024*A	high	heavy	heavy	no	poor	5.413386	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-025*A	high	moderate	heavy	no	poor	8.858268	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-026*A	high	heavy	heavy	no	poor	5.905512	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-031*A	high	moderate	moderate	no	poor	10.9252	yes	Oct-10	horticulture oil/foliar spray	safari/soil injection		light			
Tsuga canadensis	H16	97-047*A	high	moderate	moderate	no	poor	8.661418	yes	Oct-10	horticulture oil/foliar spray	merit/soil injection		moderate			
Tsuga canadensis	E21	35-6124*AA	low						no,control								
Tsuga canadensis	A19	35-6124*B	low						no,control					high			
Tsuga canadensis	E21	35-6124*BB	low						no,control					high			
Tsuga canadensis	A19	35-6124*C	low						no,control					high			
Tsuga canadensis	F17	35-6124*S	low						no,control					high			
Tsuga canadensis	B19	48-823*EE	low						no,control					high			
Tsuga canadensis	B19	48-823*FF	low						no,control					high			
Tsuga canadensis	B19	48-823*HH	low						no,control					high			
Tsuga canadensis	B19	48-823*JJ	low						no,control					high			
Tsuga canadensis	K21	48-823*L	low						no,control					high			
Tsuga canadensis	K21	48-823*MM	low						no,control					high			
Tsuga canadensis	B20	48-823*NN	low						no,control					high			
Tsuga canadensis	B20	48-823*OO	low						no,control					high			
Tsuga canadensis	H17	97-011*A	low						no,control					high			
Tsuga canadensis	H17	97-013*A	low						no,control					high			

TITLE: **REDESIGN OF THE ORANGE BALUSTRADE**

AUTHOR: **Carolyn J. Catani**
The Alice & J. Liddon Pennock, Jr. Endowed Horticulture Intern

DATE: **April 2011**

ABSTRACT:

The Orange Balustrade has been a favorite garden in the Morris Arboretum for over a century. Today it is a quiet retreat and a meditative space with the peaceful sound of water. What many visitors do not realize is that this seemingly undiscovered space was once a major focal point in the garden, an entrance, and a property edge. The balustrade has seen dramatic changes, many of which have changed the growing conditions within. The soil has become a challenge for growing even the hardiest plants and the fully grown trees provide deep shade. The objective of this project is to refurbish the garden by planting hardy perennials suitable for the conditions of the area, examine and possibly alter circulation patterns, and reconnect the structure with the overall context of the Morris Arboretum.

Redesign of the Orange Balustrade

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HISTORY OF THE ORANGE BALUSTRADE

The Orange Balustrade was created shortly before 1900 and served as an entrance into the rest of the Morrises' property. It was bordered by a boxwood hedge that expanded up to the top of the hill, creating a garden room. The garden also once marked the edge of Compton from what is Gates Hall today.

The garden was made in the Italianate style, mimicking elements such as hillside gardening, the rock wall, stream and waterfall, balustrade, and terrace. The stairs marked the beginning of a series of elaborate Victorian garden rooms that stretched down the hillside through the hill and water garden, terminating at a rose garden next to the swan pond. This hill was once a major garden axis and included many of the important plants that are a part of our collection today.

Over the years the conditions of the garden have drastically changed. When the balustrade and water feature were built, the hillside was sunny and the soil was fertile. As the trees in and around the garden grew, the ground became covered in dense shade and the soil compacted from the root growth. Though the area was shaded, the soil was very dry due to the southern exposure, steep slope and fast drainage.

In its early years as an institution, the Morris Arboretum's gardens were left to be taken care of by at the University of Pennsylvania. The early goals of the Arboretum changed from that of extravagant gardens to plant collections and cataloging. Some of the plants were moved around during this time to create collections within species, such as the magnolias, dogwoods, and hollies.

After years of neglect many of the gardens had become overgrown and the structures were in disrepair. Dr. F. Otto Haas became a chair on the Advisory Board of Managers in 1978. His work on behalf of the Arboretum helped bring it out of disrepair and helped expand the educational resources, beginning the dream that John and Lydia had when they first purchased the property in 1887.

After 1978, many changes were made to all of the gardens. The Orange Balustrade was no longer connected to the Compton mansion due to its demolition in 1968. The garden no longer served its original purpose as an entrance from the mansion and it became disconnected from the gardens below when they were removed. The Pennock Flower Walk and Maloney Gardens were installed in 2007, partially restoring the axis. The Orange Balustrade still is somewhat secluded from the rest of the garden, which is possibly why the garden is still successful.

In 2010 the garden renovations began with the reconstruction of the water feature. After years of growing, the once small *Styrax japonica* (Japanese styrax) and *Syringa reticulata* (Japanese tree lilac) had grown so large that the roots had dislodged many of the rocks in the water feature. With a generous donation from the Cilio family the rocks were reset and mortared into their original places. Another renovation that took place was the drainage system at the top

of the wall. Preventative measures were taken to divert ground water from the stone wall in order to help its preservation. This, however, made less water available than before, allowing few plants to thrive, let alone survive, in what had become a difficult growing environment.

SITE CONDITIONS

There were three main challenges to replanting the Orange Balustrade: shade, compaction, and lack of water. Dry shade is perhaps one of the toughest environments in which to grow plants. Though there are plants that can grow in dry shade, the older trees in the Orange Balustrade have caused the soil to become severely compacted. The root systems in these large trees have been growing since before 1900 and infiltrate almost all of the planting beds, leaving little space without compaction. Some of the construction work from the fountain restoration also caused the soil to become greatly compacted within the beds.

The garden has traditionally been a dry place due to its steep slope; however, in recent years the problem has increased. Another part of the restoration of the garden was to preserve the newly renovated fountain and the existing stone wall. Water would flow downhill and gather at the balustrade causing long-term harm to the structure. By diverting the runoff at the top of the hill and pointing it around the balustrade, as well as installing drainage in the path above the wall, the water will cause less harm and hopefully lengthen the life of the structure.

With the lack of water even greater than in years before, the plants are struggling. The plants that have been able to establish themselves in the Orange Balustrade thus far are: wild ginger (*Asarum canadense*), liriope (*Liriope muscari*), male fern (*Dryopteris filix-mas*), dwarf sweetbox (*Sarcococca hookeriana*) and epimedium (*Epimedium grandiflorum*). These perennials can not only grow well in dry shade, but they are aggressive. Even the most aggressive growers have had trouble thriving. For example, the liriope that was growing in the corner near the summer house was the most established patch in the garden. The plants looked as if they were only planted two or three years ago when in fact they planted around 10 years ago, at the same time the liriope was planted in the Pennock Flower Walk.

DESIGN STRATEGY

When choosing a design for the Orange Balustrade, it was difficult to ask for opinions from others. The garden, though slightly bare, has remained a favorite or "sacred" spot for many who visit or work at the Arboretum. It was important to listen to opinions from staff, board members, and directors; however it was also important to remember that each person liked the space for a different reason. Keeping this in mind, although many good thoughts and points had been raised, many of them were conflicting. The most important aspect of the Orange Balustrade is the history and the changes that have occurred throughout the years, making the garden what it is today.

The goal was to use the 1909 Atlas of Compton and formulate a circulation and planting bed design that best fit with the historic plans and best accommodate the obstacles for growing. Also just as important as the inside of the garden is the context of the Orange Balustrade within the rest of the Arboretum. By reinforcing the older elements that once linked the pathways and

views to the other pathways and features in the garden, it brings continuity and purpose back to the space.

For example, the original pathway that led into the top of the garden is no longer the main entrance. Visitors to the garden today primarily enter from the bottom, walk to the bridge at the top, turn around, and exit the way they came in. By showing a hint of the path that once connected the bridge to the Morrises' home, it tells people that they are not at a dead end, but rather that there is something more. It also piques the visitor's curiosity to explore parts of the Arboretum where they have never before been. Signage at the top of the garden explaining the "lost path" to the mansion is an important teaching tool that would make a great addition to the garden.

That the Orange Balustrade was once the entrance from the mansion was an important connection to restore, but arguably the greatest connection for the garden is the central axis that once led to the Swan Pond. Today the connection is made between the Orange Balustrade, Maloney Flower Garden and Pennock Flower Walk. These two lower gardens are special to the Arboretum because they house so many tropical plants due to their sheltered, south-facing location. The contrast between the two garden areas is dramatic in terms of sun and shade and the Orange Balustrade often gets lost in the shadows. The goal is not to put a walkway between the two, but rather to subtly show the connection. By straightening the bed edges on either side of the grass walkway leading to the base of the balustrade, the visitor's eye is drawn up, connecting the straight pathways of the Maloney Flower Garden and Pennock Flower Walk.

Another important way of connecting the three gardens is by texture and color. In a garden, color and texture play important roles in where your eye rests. The eye will focus and rest on calming views such as meadows, lawns, and ponds. When many different textured plants are planted close together, creating a busy massing, a person's eye will usually pass over it quickly. By planting up to the edges of the turf on both sides of the mown path, it creates a stronger sense of a path or entrance by allowing the viewer's eye to rest on the grass path.

By using the color scheme from the gardens below, the design of the Orange Balustrade plantings will visually reinforce the axis. The connection allows the viewer's eye to look beyond the turf between the gardens and acknowledge the background. The planting beds below the balustrade will be planted with a mixture of plants from the Maloney and Pennock gardens. The taller plantings from the lower gardens will be placed in front of the shorter plantings from the Orange Balustrade. This will create an illusion: when standing below the garden, the plants will fit with the context of the lower gardens, and when standing in the Orange Balustrade looking out, it will look as if there is a mix of plantings, reading as one garden.

SITE AMENDMENTS

With such difficult growing conditions, improvements must be made to increase the chance of survival and hardiness of the new plantings. There are only a few improvements that will be made to the site. An air spade will be used, with help from the arborists, to loosen soil around the roots of the *Styrax japonica* and *Syringa reticulata*. This should help with soil compaction that has been caused by the roots and unwanted pedestrian traffic in the beds. The soil is not only dry and compacted but also contains substantial clay and gravel. The air spade will help break up the soil not only for the health of the trees, but also for the health of the new plantings.

Mulch will be added to the top once the air spading is finished. Only an inch or two will be added, which will supply enough nutrients to the plants without raising the beds too much. The existing beds are already raised a few inches above the pathways and once the air spading is done it will be higher still with the added air to the soil.

HARDSCAPE IMPROVEMENTS

The Orange Balustrade has a strong structural presence. The stone, gravel paths, bridge, summer house, and fountain lay the framework for the garden. Originally the paths were maintained with a single meandering walk that bypassed the summer house. Now the garden is criss-crossed with "desire lines," or pathways created by visitors on their own. By restoring the pathways and connecting paths, the garden should have a better and clearer path system that will keep people from wandering through the plantings, as well as eliminate pathways with dead ends.

The first improvement is to level off the stone steps that are placed within the garden on the gravel path. These steps are shorter than the usually six or seven inches tall and have a sloped landing making them uncomfortable to walk on. The last step down the hill next to the summer house will be taken out. The step was placed so close to the structure that after stepping off down people must step up onto the structure almost immediately. This is not only awkward for the pedestrian but also causes them to look down to avoid tripping when they should be looking out at the garden.

The second improvement is to create an alternate route around the summer house. In the 1909 atlas the original path was shown bypassing the summer house. By recreating a path there, it will provide privacy for people who may be sitting on the summer house benches or a cut through for people who either want to pass through the garden or get closer to the flowers. This will be done with stepping stones that will match the other stonework throughout the garden. The third proposed improvement is to put in a small, subtle mulched path at the end of the balustrade opposite the summer house. The path would lead to the bench on the side of the hill which is a rarely explored area of the garden and an often missed view.

PLANT PALETTE AND DESIGN

The plant palette centers on the existing plants that were proven to grow in the harsh conditions of the Orange Balustrade. About fifty percent of the area will be covered with those species; wild ginger, liriope, male fern, dwarf sweetbox, and epimedium. Other plants were added that are not only grow well in dry shade but are also aggressive growers. These will make up the other fifty percent of area coverage. It is important to have plants that are aggressive for this garden because even the toughest existing plants have not thrived after being established for at least ten years.

The plant palette's main colors are similar to that of the Pennock Flower Walk and Maloney Flower Gardens that are based on the colors of the sunset. These colors will not only tie together the three gardens but will be a nice bright addition to the deep shade. Listed below in Table 1 are all of the plants included.

MAINTENANCE

A maintenance schedule will be put into place after planting to ensure proper care of the plants and upkeep of the garden. This schedule will help maintain the intended plantings and the existing plantings in years to come.

A layer of mulch one to two inches thick will be needed once or twice a year for suppressing weeds, controlling soil temperature, adding to the aesthetics, and improving plant health. Leaf mulch or triple-ground mulch is recommended over wood chips. These mulches knit together, which will help the mulch stay in place on the slope and not wash down the hill. Regular weeding should be done by hand. No chemical spraying should be done in the beds due to the close plantings and the possible threat to the health of the older trees. Spraying may be done in the gravel paths to keep weeds down.

CONCLUSION

The Orange Balustrade has changed substantially throughout the years, and these changes are what make the garden special. The new plantings are meant to enhance the garden to what it has become, not to restore it to what it used to be. By fixing circulation, strengthening views and axis', and by adding plants that will add year long interest to the garden, it becomes a more complete space, a teaching area, and a garden to be enjoyed by all throughout the year.

REFERENCES

Pape, Christine. 2010. Always Growing; The Story of the Morris Arboretum.

TITLE: PRACTICAL AND INNOVATIVE: A DESIGN FOR A NEW FIELD NURSERY AT THE MORRIS ARBORETUM

AUTHOR: Danica Doroski
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DATE: April 2011

ABSTRACT:

The Morris Arboretum is an exceptionally beautiful place to learn about and appreciate trees from around the world. Before these incredible specimens make their way out to the garden, many of these plants will spend at least part of their life in the field nursery. Unlike commercial nurseries where large quantities of relatively few species are grown, the field nursery at the Morris Arboretum serves a more dynamic role hosting a wide array of tree and shrub species from all over the world.

The purpose of the nursery at the Arboretum is threefold: to offer a more hospitable growing environment for plants that do not grow well in pots; to provide a space for trees to grow larger in size before being planted out; and to test the hardiness of a tree species. Some of the important considerations in designing a new field nursery are location, spacing, irrigation, weed control, fertilization, fencing, and shade structure. Given these considerations, a new nursery will be designed to minimize maintenance and environmental impact while at the same time creating an optimal environment for the young plants of the Morris Arboretum to thrive until they reach their ultimate destination in the landscape.

Practical and Innovative: A Design for a new Field Nursery at the Morris Arboretum

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INTRODUCTION

From time that seeds germinate at the greenhouse until they are planted out as young trees, most of the woody species at the Morris Arboretum will have a brief stay in a field nursery. Unlike conventional nurseries where many individuals of the same species are grown to maximize yield in a limited space, the field nursery at the Morris Arboretum provides a more dynamic role. The purpose of a field nursery at the Morris Arboretum is threefold: to provide a place to grow plants that do not grow well in pots (like *Quercus spp.)*, to provide a space for trees to grow larger in size before being planted out, and to test the hardiness of tree species.

OLD FIELD NURSERY

While well intentioned, the old field nursery became a black hole of the Arboretum (quite literally in fact, there was a sink hole in one corner). Like many conventional nurseries, the space was surrounded by cyclone fencing buried 1-2 feet below ground to keep out both deer and rodents. The nursery was divided into two fenced-in plots, one 50 x 103 feet and the other 60 x 100 feet. Given the space constraints and the fact that trees were planted too closely together, extraction became an ordeal especially when trees were not planted out in a timely fashion. Initially weed control consisted of several applications of Roundup along with pre and post emergent weed controls (Ulrey 1988). In 2005 intern Mark Binder suggested that the Arboretum use fine fescue as an inter-crop planting. This turned out to be a fairly effective biological weed control. Overhead irrigation on a metal tripod and oscillating sprinklers were used to irrigate the nursery.

When the new horticulture building was built on the Bloomfield Farm, a parking lot replaced the old field nursery. This provides an excellent opportunity to "start from scratch" with a new field nursery design so that some of the old problems might be re-thought and the successful aspects repeated. The ultimate goal of the new field nursery design is to be low-maintenance, low impact, functional, and provide flexibility in its design for years to come.

COMPONENTS OF THE FIELD NURSERY

There are several important considerations in any field nursery design. These include: site selection, size, spacing, irrigation, fertilization, weed control, pest control, and some form of shade structure.

LOCATION

For convenience sake it seems logical to place the nursery near the greenhouse operation, however; space-wise only the Bloomfield Farm side of the Arboretum is suitable. The old weather station located behind the magnolias near the horticulture center garages has been selected as the future nursery site. This space is relatively flat, with a gentle slope to allow for drainage (Heuser and Stinson 1988). There is water access from here with four hose bibs located in close proximity. This site is also conveniently located near the road.

SIZE

Nurseries can range in size from petite 60 x 60 foot enclosures that can be seen at Scott Arboretum or as sprawling as the multi-acre operation at Longwood gardens. We do not need a tremendous amount of space for our nursery at the Arboretum but we are wary of falling into another situation where we are tight for space; a 100 x100 foot plot should comfortably suit the needs of the Arboretum. Additionally for ease of tree extraction four large (12 foot wide) gates will be placed on all four sides of the nursery so that if needed, a backhoe, tree spade and mower can all enter.

SPACING

Within the nursery plot the spacing of trees is also very important. On average most nurseries, including Scott and the Arnold Arboreta, have a spacing scheme with 4-5 feet between rows and 5-6 feet between plants. At large production nurseries such as Rhode Island Nursery, as little as three feet may be left between rows. However, lest we are doomed to repeat the past, there should be ample space between trees at our new nursery. If we leave two feet on either side of each tree, and then six feet of lawn in between, the plantings will have 10 feet between them. This will leave plenty of space to grow and allow large machinery and mowers to move through easily. Rows should run east to west to follow the path of sunlight through the day (Bill Barnes, personal communication).

Crop rotation is also important so that the soil has time to recover after each planting cycle. Arnold Arboretum uses only two of their three nursery plots and then sows the third plot with winter rye leaving it fallow for a year. At the Morris Arboretum we will have enough space to leave one half the nursery fallow and plant the other half and then rotate each half annually.

IRRIGATION

There are two schools of thought in the great irrigation debate; overhead vs. drip irrigation. Overhead is by far the simplest and cheapest option; this is used at both the Scott and Arnold Arboreta where the nursery itself covers a relatively small space.

At larger nurseries such as the one at Longwood Gardens, drip irrigation is used. Drip irrigation is advantageous in that it conserves water, decreases the risk of foliar disease from leaf

wetting, and limits run-off (Davidson et al. 2000). Drip irrigation also aids in root development and more effectively limits weed growth by directly applying water to the area around the plant. However, like everything in life these benefits come with a cost. In 2005 intern Mark Binder got an estimate from Dave Cook at Trickl-eez in Biglerville, PA. For the parts and labor, drip irrigation at the Arboretum totals up to a substantial price.

I think that drip irrigation would be an interesting option for the Arboretum to pursue at some point but given the size and current budget of the nursery overhead irrigation may be the most practical option. Additionally, drip irrigation could always be incorporated into the nursery design in the future. A third "in between" option would be soaker hoses. Soaker hoses are relatively cheap and low maintenance; hoses could be run down each row and set to timers to soak the soil without the wasted water associated with overhead irrigation.

WEED CONTROL

Weed control is another vital component of tree nursery management. Left alone, weeds have the potential to out-compete the tree species planted by using up light, moisture and nutrients in the soil (Davidson et al. 2000). Controlling these weeds can be an incredibly labor and time intensive process depending on the method chosen.

Most nurseries, including the Arnold and Scott, use multiple rounds of the herbicide Roundup (*glyphosate*) accompanied by hand weeding. While this method is effective, I do not think that it is the best option for the Morris Arboretum for many reasons; *glyphosate* application is both expensive and labor intensive requiring Arboretum staff to properly protect themselves and spray several times a year. Furthermore, *glyphosates* are toxic and have been linked to mutations in aquatic animals and invertebrates (Buffin and Jewell 2001). Given the proximity of the nursery to the Wissahickon watershed and 100-year floodplain, I believe the Arboretum should minimize its use of this and other toxic products.

One way to limit weed growth is with biological controls such as a cover crop. At Longwood Gardens lawn is left between tree rows and periodically mowed to keep weeds down. The immediate area around the tree is mulched and then hand-weeded.

This option was the subject of an intern project in 2005 in which Mark Binder suggested the use of a cover crop as an inter-crop planting. Living mulches or cover crops are beneficial in that they increase the soil organic matter, reduce compaction from equipment, increase water percolation, increase soil aggregates, stabilize soil, and reduce erosion (Atland 2000). There is a wealth of literature and research on preferred cover crops. Experiments have been conducted with fescues (*Festuca*), rye (*Secale*), trefoil (*Lotus*), rye grass (*Lolium*), and members of the family *Brassicaceae*.

In the book, Managing Cover Crops Profitably, the authors extensively outline the advantages and disadvantages of each cover crop. I believe that *Brassica napus* in the family *Brassicaceae* could be an ideal cover crop to be used at the Arboretum. This species produces a

glucosinolate-containing residue; this residue suppresses plant-parasitic nematodes and soil-borne disease (Snapp et al. 2005). *B. napus* is also effective at weed control because the glucosinolate residues it produces are also toxic to weeds and fungal pathogens (Haramato and Gallandt 2004). These glucosinates also have been found to limit generalist insect feeding (Haramato and Gallandt 2004). When compared with other cover crops Brassica is most effective at capturing excess nitrate and therefore preventing nitrogen loss (Snapp et al. 2005). Given all the advantages that this cover crop species has to offer it would be interesting for the Arboretum to experiment using it in inter-crop plantings in the future.

Another potentially useful cover crop species is *Festuca longifolia.* This species was recommended and implemented by intern Mark Binder. This species, like *B. napus* reduces erosion, limits weed growth, but does not inhibit tree growth. Additionally, this species does not spread laterally as it grows making it easy to control and only needs to be mowed a few times a year (Binder 2005).

While I do think that the Arboretum should experiment with cover crops in the *Brassica* or *Festuca* family in the future, at least for the first year it seems most practical to leave the existing cover crop in the nursery with either rows or rings of wood chips. Curator Tony Aiello suggested the use of wood chips over mulch because they do not change the soil chemistry as dramatically. Finally, as needed, chemicals such as Roundup or hand weeding can be used as a last resort.

FERTILIZATION

While most commercial nurseries use some sort of fertilizer be it in slow release, liquid, or dry form, this component is of much less importance at the Morris Arboretum. Local expert Bill Barnes also points out that the less we "baby" trees in the nursery the more likely they are to be successful once they are planted out in the landscape where conditions will inevitably be harsher. Additionally, given that the Arboretum was unable to keep up with tree growth in the old nursery, the use of fertilizer seems counteractive to our intent.

PEST CONTROL

At the Arboretum we have another four letter profanity; deer. Deer and rodents are some of the worst Arboretum pests and given our proximity to the Wissahickon woods the chances of eliminating these irksome creatures are slim. Thanks to fencing we can coexist. There are two deer fencing options; one is the Benner Deer Fence that can be seen under the "Out on a Limb" exhibit or at the Scott Arboretum. The more conventional option is the cyclone fence used at Longwood Gardens; below is a quick comparison of the two options.

FENCING COMPARISON

	Benner	**Cyclone**
Appearance	High strength wire fence mesh does not stand out in the landscape	Galvanized steel or vinyl coated, fairly noticeable in landscape
Cost	$8,000	$10,000
Protection From:	Deer and rodents with additional rodent barrier	Deer and rodents if fence is buried
Height	7.5 feet	5-6 feet
Ease of Installation	Easily installed with steel pipes and ground stakes.	More involved, fencing must go into the ground, cement is used to set posts.

At other nurseries such as Colibraro's, simple cardboard blocks are constructed to protect from buck-rub. At Bigelow Nursery hanging soap is intended as a deer deterrent. However given the extent of the deer problem at the Morris Arboretum, I believe that protective fencing is the way to go.

LATHE HOUSE

A lathe house is another useful component of any nursery. The lathe house can protect plants in the summer from the heat and wind and reduce the intensity of sunlight in the winter. Lathe houses can be especially helpful for species such as *Acer* and *Rhododendron* that prefer a more protected environment (Davidson et al. 2000). These structures are also important in the winter because they protect evergreen species such as *Illex spp.*, *Camellia spp.* from harsh sunlight. (Bill Barnes, Personal Communication).

There are many different versions of the lathe house ranging from wooden lathe houses with protection on all four sides (Longwood Gardens) to structures as simple as four bowed metal poles draped with shade cloth (Colibraro Nursery or Arnold Arboretum).

Currently a lathe house is not in the immediate plans for the Arboretum nursery however, I do think this would be a worthy pursuit in the future. The lathe house should be at least 8-12 feet tall and arched to reduce snow load. The lathe house should also be placed perpendicular to the path of the sun so that plants get an even amount of sunlight throughout the day (Bill Barnes, personal communication).

BUDGET

It is difficult to estimate an exact budget for the field nursery. The nursery will be amended and altered over time and better models may replace many of the products purchased initially at a later date. However, a rough idea of the costs associated with the nursery now and into the future is laid out below.

Site Preparation		
Soil Test (6)	Prescription Soil Analysis	$49 each x 6 tests = $300
Water Test	Miller Pump	= $205
Till Rental		
Herbicides	In House Cost	----------
Cover Crop*	Green Cover Seed	Brassica rape $1 per lb need 8-14 lb per acre x .2 acre nursery = $2.4
Wood Chips		
Grading		$500
Fencing		
Cyclone	Glenside Fencing	$10,000
Deer Fence	Benner Deer Fencing	$7,000
Irrigation		
Hose lines	Sharkey Enterprises	$2,000
Timer (3-4)	DIG Digital	$100 each x 2 (for now the arboretum may purchase more in the future) = $200
Tripod	In House Cost	----------
Soaker Hose	Hummert	$15 each x 3 = $45
Hose Bibs (3-4)	Sharkey Enterprises	
Lathe house		
Shade cloth*	Gempler's	60% shade cloth 60' x 50' = $512.55
Metal posts*	Rimol Greenhouse Systems	Depends on size 60' x 50' = $5647

**indicates future costs*

CONCLUSION

Given the scope, price range, and purpose of a field nursery at the Arboretum I believe that current design should suit the needs of the nursery while also providing flexibility in the years to come. The development of the field nursery is a gradual process and over time elements may be added or removed to suit the needs of the Arboretum but it is hoped that these recommendations can guide the design and help get the process started.

REFERENCES

Altland, J. 2000. Weed Control in Nursery Field Productions. Oregon State University: EM8899-E.

Binder, Mark. 2005. "A Nursery For all Purposes". Morris Arboretum, Philadelphia PA.

Buffin, D. and Jewell, T. 2001. "The Implications of increased use of glyphosate in association with genetically modified crops." Pesticide Action Network.

Calkins, J. and Swanson, B. 1995. "Comparison of Conventional and Alternative Nursery Weed Management Strategies." Weed Control. 9:761-767.

Davidson, H., Mecklenburg, R. and C. Peterson. 2000. Nursery Management: Administration and Culture. 4th ed. Prentice Hall; Upper Saddle River, NJ.

Duruz, W. 1950. The Principles of Nursery Management. A. T. De La Mare Company, Inc.; New York.

Haramoto, E. and Gallandt, E. 2004. "Brassica cover cropping for weed management: A review." Renewable Agriculture and Food Systems. 19 (4):187-198.

Haramato, E. and Gallandt, E. 2005. "Brassica cover cropping: I. Effects on weed and crop establishment." Weed Science. 53:695-701.

Hueser, C. and Stinson, R. 1989. Nursery Production. 2nd ed. Pennsylvania State University; University Park, PA.

Managing Cover Crops Profitably. 1998. 2nd ed. A publication of the Sustainable Agriculture Network. Beltsville, MD.

M. Froment, A. Chalmers, C. Collins, J. Grylis. 1999. "Rotational set-aside; influence of vegetation and management for one-year plant covers on soil mineral nitrogen during and after set-aside at five sites in England." Journal of Agricultural Science, Cambridge. 133: 1-19.

S.Snapp, S. Swinton, R. Labarta, D. Mutch, J. Black, R. Leep, J. Nyiraeza, and K. O'neil. 2005. "Evaluating Cover Crops for Benefits, Costs, and Performance within Cropping System Niches." American Society of Agronomy. 97: 322-332.

Ulrey, Chris. 1989. "New Nursery Management Practices to Aid in the Production of Quality Plant Material at the Morris Arboretum." Morris Arboretum, Philadelphia, PA.

Nurseries visited:

Arnold Arboretum; Boston MA

Colibraro's Nursery; Willow Grove PA

Sam Brown's Nursery; Malvern PA

Scott Arboretum; Swarthmore PA

Longwood Gardens; Kennett Square PA

Rhode Island Nursery

Bigelow Nursery

Knowledgeable people:

Aiello, Tony, Director of Horticulture

Anderson, Bob, Director of Physical Facilities

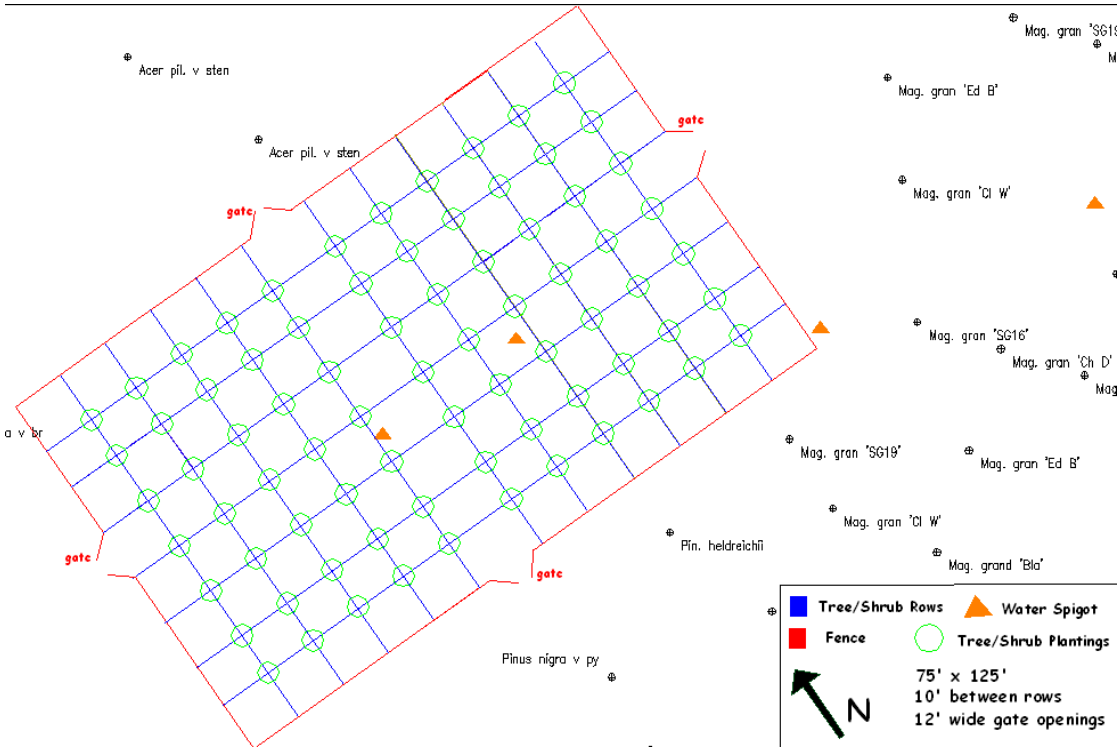
Barnes, Bill, Owner, Lorax Nursery

Catani, CJ, Horticulture Intern

Clarke, Louise, Natural Areas Section Leader

Dillard, Shelley, Propagator

APPENDIX A: New Nursery Map



TITLE: **EDUCATION UPDATES ON THE WEBSITE**

AUTHOR: **Sara Levin**
The McLean Contributionship Endowed Education Intern

DATE: **April 2011**

ABSTRACT:

The goal of this project was to make the Education Department's presence on the web site more current and diverse. I focused on four major areas to update: General Public Education, Classes, the Internship Program, and Tours. In each area I updated the existing text and photographs and added new material that would make the Morris Arboretum web site more interesting and easier to navigate. In general, my goal was to make the Morris Arboretum web site a part of the public's visit the Arboretum; a place that visitors would go before, during and after their actual visit to the Arboretum grounds for a tour, an internship or a day time visit.

Education Updates on the Website

TABLE OF CONTENTS

GOALS

Web sites are the modern face of public institutions. An updated and user-friendly web site attracts more visitors to the web site that in turn attracts more visitors to the physical site itself. Internet users respond to pictures and concise text. The average time a visitor spends on a web site is under 1 minute[15]. Therefore, we have a small window in which to catch visitors' attention and successfully inform the visitors about our various educational programs. The Education Department at the Morris Arboretum was in need of better representation on the web. My project looked at the needs of the Education Department on the web site and where subtle or significant changes could be made, with a focus on adding depth to the web site and ease of use. I divided Education on the web site into four categories: General Public Education, Classes, Internship Program, and Tours. Within each category, I researched other botanical gardens and arboreta to see what else was out there and what seemed to be working to promote educational programs at other gardens. I then set the goal to accomplish a series of tasks in each category during my year as education intern.

RESEARCH

I selected several gardens and arboreta that shared common mission statements and studied their web sites and their placement in search engines such as Google and Bing. The gardens and arboreta I researched included Chicago Botanic Garden, Morton Arboretum, New York Botanical Garden, Denver Botanic Garden, Brooklyn Botanical Garden, and Longwood Gardens. The web sites of these institutions each had some element of interest and I was particularly interested in the use of videos and self-guided tours. I also looked at the internship programs offered at institutions such as Arnold Arboretum and BBG to get a sense of how well we are advertising our internship program. Based on this research I determined the way in which Education on the Morris Arboretum web site could be better accessed and utilized. As a part of my research, I also attended a workshop on "Getting results from your online marketing" in the early summer to get more advice on how the public generally views a web site and how to maximize a visitor's time there.

IMPLEMENTATION

First I evaluated what we already had in place and what changes could be made. I met with Zac Brooks, Arboretum web manager, several times to discuss the process we would use to create and upload new material. I selected four categories in which to work: general public education, classes, internship program, and tours. In each category I selected a minimum of two areas of improvement. My project took place over the course of the year with the help and

[15] Based on Google Analytics

review of my supervisors, Jan McFarlan and Liza Hawley, as well as Lisa Bailey, Zac Brooks, Tony Aiello, Susan Crane, and Tim Block.

General Public Education

My goal in this area was to add activities and information to the web site that would encourage the public to log onto the web site before, during, and after their visit. In the area of General Public Education I created a monthly "What's in Bloom" map for each month so that returning visitors would have a fresh look at the collection each month. I added a new downloadable self-guided Wetlands Tour to encourage visitors to learn more about a unique and often under visited garden feature. I also helped develop rack cards targeting a younger audience with a supplementary sheet of seasonal activities to be found online that encourage visitors to use our web site to find nature based activities that can be done at home or at the Arboretum.

Classes

Classes are valuable programs and the Arboretum has established an excellent reputation for offering high quality educational courses. However there are still some classes that remain unfilled and I hope to use the internet to both ease class selection and to advertise upcoming or annual classes. I have also been working to create a post-class online survey and advertize the course catalogue through online videos. The online survey is off to a good start and beginning to bring in some valuable feedback and the videos will hopefully be completed this May (2011).

Internship Program and Tours

The internship and tour pages needed a major upgrade. In both areas the photos and content were out of date, the writing was verbose and the pages were difficult to navigate. First I added many updated photographs on the intern and tour pages. On both pages I changed the text and layout to create a format that was easier to navigate and was filled with more concise language.

The internship program is one of the best programs in the country. My goal for the internship program was promotion. In my first week on the job I created a Facebook page for current interns, alumni and friends of the program. Facebook is the format in which young people communicate, socialize, and connect with each other. The Morris Arboretum Facebook page creates a space to reach current and past interns while advertising the internship program (through the many pictures of our Thursday sessions) to potential interns. In another attempt to promote the internship online, I made sure that the intern positions were advertised on popular job sites such as Craigslist, Philaculture and the APGA. I also signed up for Google Alerts for the phrase "Morris Arboretum Internship" so that whenever the internship program was referenced online I would receive a notice and could see who was referencing the program and in what context.

Part of the mission statement and original will of John and Lydia Morris is the encouragement of stewardship. The tours for all ages embody the mission of stewardship. The tour pages were updated in order to be more accessible to teachers and schools and in order to provide more information to potential group tour participants.

CHALLENGES AND ADJUSTMENTS

My greatest challenge was the completion of the Wetlands Tour. I began the initial outline and research in the fall and the first final draft was completed in January. It was still in need of work and due to inclement weather and the struggle of learning about the wetlands while at the same time trying to produce an effective and educational tour, the process proceeded slowly. At the beginning of the intern year, I anticipated making several self-guided tours during my time here but I did not anticipate how long the process can take. An added obstacle was the many check-points this tour went through, so the time it took for other staff members to review and edit the tour as well as the conflict of my many other obligations that often took precedent over the finishing the wetlands tour once and for all. It is still a goal of mine to create one more self-guided tour before June.

The greatest adjustment I had to make in my plans was in cancelling the creation of audio tours. In my initial research I was impressed with audio tours in podcast format such as the mural arts tours of Philadelphia. After surveying the Arboretum visitors on a very busy day in the fall (Black Friday), I realized that energy would be misspent on audio tours. I surveyed about 50 people and asked the following questions:

Did you look at the Morris Arboretum web site before your visit today?
Did you know about the new seasonal family activities and self-guided what's in bloom maps available on the web?
In what area would you like to learn more about the Arboretum?
(for those who seemed stuck on coming up with their own idea, I had a list of possible themed tours including: History of the Morrises, The Fernery, The Garden Railway, Medicinal Trees, Native Plants, and Edible Plants). I also was given a few suggestions for tours, including: Tree Identification (go find specific trees), Fragrant Plants, Birding, Educational Tours for Kids, and The Rose Garden.

Would you enjoy listening to an audio tour at the Arboretum? (2 yes responses only)

The most valuable opportunity I had that day was observation. I realized that though the Arboretum is a living museum, its visitors do not travel through the Arboretum in the same way they would a museum. People tended to travel in groups, even those who had been here many times came with other people. There were many family groups and there was a lot of interaction between people in the group, unlike an art museum, for example, where families often split up and rejoin each other several times throughout the visit; at the Arboretum, people stuck to their groups and to change the dynamic, by encouraging the use of headphones, would seem to disrupt the standard way in which people visit the Arboretum.

FEEDBACK

Google Analytics was used to trace the activity on the new web pages. I checked in several times throughout the year and was pleased with the results but would like to see even more activity. Advertising the new features of our web site would help inform the public that the web site is now a place to go to learn about horticulture and download fun and interesting activities. An article in the local Chestnut Hill newspaper would help raise awareness, as well as continuing to place the Arboretum's web address on every publication we create.

FUTURE WORK

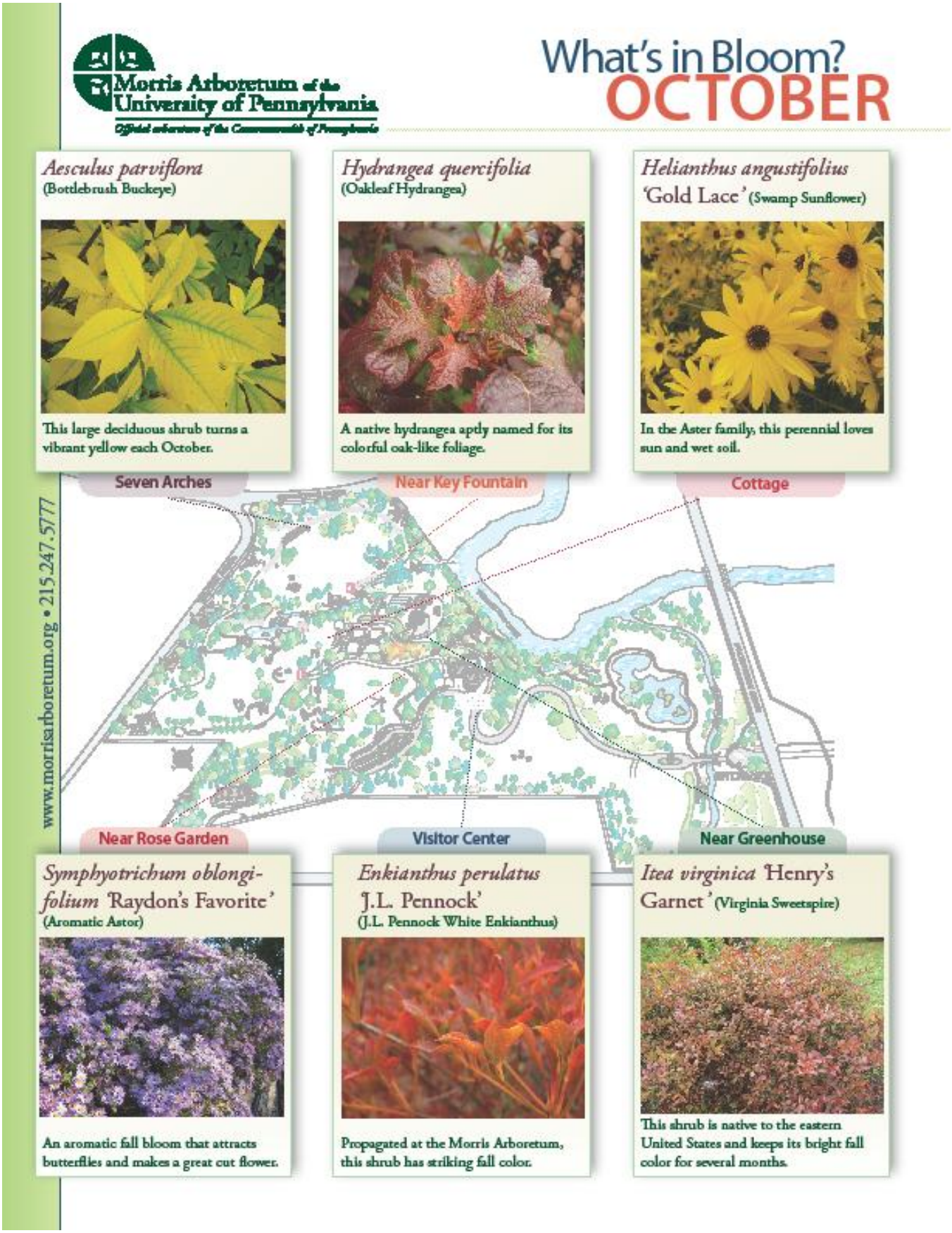
The final piece of my project is to produce a series of videos for the Web site. The videos will be filmed and edited by Joe Cozza, for his senior project at Chestnut Hill Academy. Video topics will include "how-to" videos: pruning roses, green roof, greenhouse, arboriculture and events such as the Japanese Cherry Blossom Festival, the Plant Sale and weddings.

CONCLUSIONS

Many small but significant changes have helped the Morris Arboretum's web site become a fresher and easier site to navigate. A current and updated web site puts our best face forward to members and potential visitors. I believe my work has helped show the public why the Arboretum is such a valuable educational institution.

Special thanks to Jan McFarlan, Liza Hawley, Lisa Bailey, Zac Brooks, Tony Aiello, Susan Crane, and Tim Block for their advice, edits, suggestions, and corrections.

APPENDIX A: What's in Bloom



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What's in Color? NOVEMBER

Fagus engleriana
(Engler beech)

Take refuge under the russet limbs of the Engler beech! It is a rare variety and one of our Great Trees.

Cercidiphyllum japonicum
(Katsura-tree)

Considered by some to be the greatest tree at the Arboretum, the katsura has great fall color and emits a sweet aroma.

Metasequoia glyptostroboides
(Dawn redwood)

The Dawn redwoods are deciduous conifers that were thought to be extinct until their rediscovery in 1941!

www.morrisarboretum.org • 215.247.5777

Ilex serrata
(Fine tooth holly)

This plant, native to Asia, provides a bright splash of color on the Oak Allée.

Lindera salicifolia
(Willow-leaved spicebush)

The long fountain is brought to life, surrounded by the bright colors and spciy scent of this Laurel family shrub.

Acer palmatum
(Japanese maple)

Vibrant varieties of Japanese maple dot the Arboretum grounds with color this month!

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Winter Interest
FEBRUARY

Eranthis hyemalis
(winter aconite)

This member of the buttercup family (*Ranunculaceae*) provides a bright splash of color in late February.

Hamamelis mollis
(Chinese witchhazel)

Fragrant witchhazel of several varieties ushers in spring around the Arboretum!

Galanthus (snow drops)

Named for its milk-white petals, this is one of the earliest blooms in late winter.

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Chimonanthus praecox
(wintersweet)

Native to China, wintersweet adds fragrance and color to the Oak Allée.

Hamamelis x intermedia 'Rubin' (Rubin witchhazel)

This bright pink cultivar is a hyrbid of *H. mollis* and *H. japonica*.

Hammamelis x intermedia 'Pallida' (pale witchhazel)

The late winter flowers of this plant bloom before the spring foliage emerges.

APPENDIX B: Wetlands Tour

Wetlands Tour

Morris Arboretum *of the* University of Pennsylvania

What Are Wetlands?

Wetlands are areas of land that are saturated enough with ground water that they can support flood tolerant vegetation or plants that require wet soil. Wetlands are transition zones between dry land and deep water.

Why Are Wetlands Important?

Wetlands are a home and refuge to a great biodiversity. Wetlands collect rain and ground water and act as a filter, slowing down and cleaning the water. Wetlands can also hold excess water during a storm to prevent overflow into the sewer system.

History of the Morris Arboretum Wetlands

1717 This parcel of land was deeded to John and Lenart Streeper by William Penn. It was used for farming and mining of iron ore and limestone.

1892 Floodplain purchased by John and Lydia Morris to add to their Compton estate. A cow barn was built at the top of the slope and Jersey cows were pastured down the slope to the Wissahickon Creek.

1910 In order to create better land for grazing, John Morris installed drainage tiles that successfully drained the wetlands adjacent to the creek for better pasture lands.

1932 Morris Arboretum was founded upon the death of Lydia Morris. The lower slope and meadow were leased by the Arboretum for grazing and hay production until the 1950's. Beef cattle grazed here during WWII to supply the war effort.

1996 The Arboretum proposed a Paper Mill Run restoration and demonstration project that began in 1998.

2001-2 Thanks to funds from the Pennsylvania Department of Environmental Protection and the E.P.A. to restore the wetlands and meadows as demonstration sites for ecological land management. Initial installation began in 2001-2 and plantings continue today. The underground tiles were broken and natural spring water was able to flow through the flood plain once again. The water level can be adjusted to control vegetation or to prepare the area to receive runoff from a major storm.

Today, the Arboretum's wetland area has been restored to its original function.

Your tour

The wetland and its floodplain encompass about 35 acres of the Arboretum. Today we will focus on the pond and its immediate surroundings. Park in **the floodplain, left of kiosk and walk south-west to the wetland. Keep your** ears and eyes open for the animal and plant life that thrive in our wetlands.

Find these native plants:

1. *Viburnum dentatum* (arrow-wood viburnum) 2002-365*A
2. *Cercis canadensis* (eastern redbud) 2003-064*A
3. *Platanus occidentalis* (American sycamore) 2002-362*A
4. *Quercus palustris* (pin oak) 2005-025*B
5. *Betula nigra* (river birch) 2001-378*A
6. *Alnus serrulata* (hazel alder) 2003-079*A
7. *Salix nigra* (black willow) 2003-124*A
8. *Cladrastis kentukea* (American yellow-wood) 54-1073*A
9. *Ilex verticillata* (common winterberry) 2004-142*A
10. *Acer rubrum* 'Frank'sred' Red Sunset red maple 2005-224*A

A Signage

Spot this wetland vegetation:

Solidago speciosa
golden rod

Vernonia novaboracensis
iron weed

Physocarpus opulifolius
common ninebark

Look and listen for these local and migratory animals:

belted kingfisher

blue heron

eastern painted turtle

Bird Boxes

The Morris Arboretum installed bluebird, wood duck, kestral and bat boxes to encourage wildlife to inhabit the area. Our wetlands are now a sanctuary both for wildlife and nature lovers!

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APPENDIX C: Seasonal Family Fun Activities

Fall Family Fun – Exploring the Changing Seasons

Autumn provides a great opportunity for outdoor exploration. Here are some great hands-on family activities that require little cost or preparation.

Autumn Journal
Create a journal from recycled paper and cardboard or use an old notebook. Fill the pages with notes, pictures, and stories about the changes you observe on a nature walk.

- Use drawings, crayon rubbings, or photographs
- Note when the leaves change color and drop
- Gather the most colorful leaves to press in your journal
- Note weather patterns, the first frost, or wildlife behavior

Keep it to compare the seasons from year to year.

Questions inspire creative thinking:
Why are the leaves falling?
Which tree do you think will lose its leaves last?
How do the leaves look, smell, and feel?

Exploration generates questions; don't be intimidated by the questions that may come up! Ask Arboretum staff and volunteers, visit The Shop, or borrow a reference book from your public library to learn more about what you're seeing.

Scavenger Hunt
Bring along a plant ID guide and a magnifying lens. Search for certain colored leaves, the biggest acorns, or different types of fruit. Imagine life as a squirrel and challenge your spatial memory by hiding acorns like a squirrel and returning later in the day to find them.

Collage and Decoupage
Bring the season's colors into your home with collages of pressed foliage. Place leaves between sheets of transparent contact paper to make placemats and bookmarks. Use decoupage glue to decorate jars, vases, cards, and other items.

Twig Picture Frames
Collect sticks to make a twig picture frame for a favorite photograph. Construct a frame by overlapping the sticks and tying with a string at the corners, or glue the sticks onto the photo as a border.

Most importantly, remember to listen with your imagination and be creative! Take advantage of the beautiful colors of fall and make it a season to remember!!

Winter Family Fun Activities

Warm up with these fun activities to do at the Arboretum and at home with your family!

"Cabin Fever" Remedy

Don't succumb to cabin fever! Get outside and enjoy the winter wonderland! Take a walk and observe how animals survive the cold months of winter! Stimulate your children's imaginations and try to imagine life as a wild animal in winter. Can you spot the berries and acorns that the animals eat? Help your furry friends find food by covering a pinecone with peanut butter and bird seeds and hang it from a tree in your yard!

Bring the Outside In!

Make sure you head outside when the snow falls and make your best snow angels and snowmen! Watch the falling snow flakes and then take the fun inside and create your own snowflakes out of paper (recycled is best).

How it works:

Cut out a circle of any size (plates are helpful for tracing). Fold the circle in half, then fold it into ¼ of a circle and finally, fold that piece once more to create ⅛ of a circle. Then snip and cut into the paper to create the design of your choice! Unfold and hang your snowflakes around your house, creating an indoor winter wonderland!

Fun Facts: How plants prepare for the cold!

The winter landscape may seem quiet, but underground, seeds are preparing for spring. Covered by a warm blanket of soil, leaves, and sometimes snow, these seeds are waiting in a state of dormancy for warmer days.

While waiting patiently for spring, the seeds are benefiting from the colder temperatures, a necessary element to ensure germination in the spring. During fall, deciduous trees and shrubs absorbed all the nutrients from their leaves into their branches and trunks, dropping the remnants in a brilliant array of fall color.

After bringing water and nutrients into the stems and trunk, trees change these nutrients into substances that will not freeze. In essence, trees create their own antifreeze allowing them to stay alive despite freezing temperatures.

Visit **www.morrisarboretum.org** for more Family Fun activities

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APPENDIX D: Zoomerang

Contemporary Tree Appraisal
Results Overview

zoomerang

Date: 3/31/2011 6:49 AM PST
Responses: Completes
Filter: No filter applied

Course Title:Contemporary Tree Appraisal

Instructor(s):David Hucker

Date: 2/18/11

3. Course Material and Organization Course Content

1 Poor		0	0%
2 Fair		0	0%
3 Good		3	38%
4 Excellent		5	62%
	Total	8	100%

4. Fulfillment of the Course Objectives

1 Poor		0	0%
2 Fair		2	25%
3 Good		2	25%
4 Excellent		4	50%
	Total	8	100%

5. Organization of the Course

1 Poor		0	0%
2 Fair		1	12%
3 Good		4	50%
4 Excellent		3	38%
	Total	8	100%

6. Overall Rating of Course

1	Poor	0	0%
2	Fair	1	12%
3	Good	2	25%
4	Excellent	5	62%
	Total	8	100%

7. Instructor(s) and Presentation Instructor(s)'s Knowledge of the Subject Matter

1	Poor	0	0%
2	Fair	0	0%
3	Good	1	12%
4	Excellent	7	88%
	Total	8	100%

8. Enthusiasm of the Instructor(s)

1	Poor	0	0%
2	Fair	0	0%
3	Good	0	0%
4	Excellent	8	100%
	Total	8	100%

9. Attitude toward Students

1	Poor	0	0%
2	Fair	0	0%
3	Good	3	38%
4	Excellent	5	62%
	Total	8	100%

10. Overall Rating of Instructor(s)

1	Poor	0	0%
2	Fair	1	12%
3	Good	2	25%

4 Excellent		5	62%
	Total	8	100%

12. How did you hear about this course?

Brochure		5	62%
Web Site		3	38%
Newspaper		0	0%
Friend/Colleague		1	12%
Other		1	12%

13. What was your main purpose for attending?

Personal Interest		1	12%
Professional Development		7	88%
Professional Certification (School of Arboriculture)		1	12%
Professional Certificate (Audubon Advisors)		0	0%
Professional Certificate (Landscape Design)		0	0%

14. What meeting time for our classes would be most convenient for you?

Weekday Daytime		7	88%
Weekday Evenings		0	0%
Weekends		1	12%

APPENDIX E: Internship Updates

Internships

1) Under ABOUT-Employment: List Internship before volunteer opportunities
2) PAGE 1:
   a) OVERVIEW: Morris Arboretum is a historic public garden and educational institution. It promotes an understanding of the relationship between plants, people and place through programs that integrate science, art and the humanities. The internship program provides hands on experience and education that prepares interns for careers in public gardens and related fields.
      i) Morris Arboretum offers year-long, full-time internships with full benefits in the following areas:
         - Arborist
         - Education
         - Flora of Pennsylvania
         - Horticulture
         - Natural Lands
         - Plant Protection
         - Propagation
         - Rose and Flower
         - Urban Forestry

         (***click here on each position to access position pages**)
3) Two pictures of current interns (1. group shot at Chanticleer 2.group shot at Society Hill)
4) PAGE 2: (listed as a link on the side of the main page or a pull down below)
   a) CORE CURRICULUM: In addition to your regular duties, the interns participate in weekly afternoon seminars and field trips and they staff the Arboretum Plant Clinic. During the year-long program, the interns are also enrolled and will receive graduate level credit for "Issues in Arboretum Management I and II" through the Department of Landscape Architecture at the University of Pennsylvania.
      i) LINK 1: Weekly seminars and practical sessions: these afternoon sessions allow the interns to interact with Arboretum staff and other professionals from various botanical gardens and arboreta. Session topics are diverse and have included:
         - The basics of beekeeping
         - History of plant exploration
         - Tree climbing basics
         - Propagation by seeds and cutting
         - Diseases of pest and ornamental plants
         - Winter botany

      ii) With two to three pictures of the sessions (tree climbing, greenhouse, beehives)
      iii) LINK 2: Field Trips: partial or full-day trips provide interns with comparisons of the operations of other managed public landscapes and natural areas. Recent trips include:

- The Highline
- Bartram's Garden
- Academy of Natural Sciences
- Chanticleer Gardens
- Beneficial Insect Research Lab
- Wave Hill
- Brooklyn Botanical Garden
- New York Botanical Garden
- Mt. Cuba Center for the Study of Piedmont Flora
- Island Beach State Park
- Reeves-Reed Arboretum
- Frelinghuysen Arboretum

iv) With two pictures (Highline, Society Hill)

v) LINK 3: Plant Clinic: staffed by interns, the Plant Clinic provides the opportunity to assist the public in diagnosing plant pests and disease inquiries as well as plant identification and general horticulture questions.
- Pictures: close-ups of plants and pests

vi) LINK 4: Issues in Arboretum Management I and II: Interns receive credit hours based in their performance each semester in the following categories:
- LIVING COLLECTIONS SESSIONS: monthly sessions focusing on trees of botanical interest in the Arboretum collection where interns will refine their skills in plant identification, use and culture. There will be a written and field exam at the end of each semester. Collections discussed include: summer blooming plants, shade trees, roses, maples, oaks, and more!
  - Pictures of trees through the seasons
- INDEPENDENT STUDY PROJECT: each intern completes an independent study project that is geared towards advancing his or her career development and the Arboretum's mission. Each project consists of an oral presentation and a written report. Towards the end of the internship program, all independent study projects are presented to the Arboretum staff.
  - Pictures of summer camp, green roof, interns at tree (old photo)

5) Page 3 (listed as a link on the side of the main page or a pull down below)
   a) ADDITIONAL INFORMATION
      i) Payment:
      As full-time employees of the University of Pennsylvania, interns work a 40-hour week at an hourly rate of $9.75. Interns must commit themselves for the full year term.
      ii) Housing:
      Arboretum staff assists the interns in finding housing by providing a list of nearby affordable options. Occasionally there are opportunities for the interns to live with hosts and exchange work around the home of their hosts for a reduced rent.
      Helpful Housing Links:
      www.craigslist.org

www.4wallsinPhilly.com
www.chestnuthilllocal.com

iii) Benefits:

- Interns receive health, dental, and vision benefits (link to health benefit page) through the University of Pennsylvania.
- Additional benefits include paid vacation time, sick days, and several paid holidays plus an administrative vacation for all staff and interns is provided between Christmas and New Year's Day.
- More Opportunities to Grow: All interns are eligible for additional tuition benefits at the University of Pennsylvania, Chestnut Hill College, and Temple University's Ambler Campus. (LINK TO UNIVERSITY WEB PAGES?)
- Interns may also sign up to take free classes from our seasonal course brochure (link to course catalogue) and are encourages to attend Arboretum-sponsored conferences and symposia that they find of interest and that will further their professional development.

6) Page 4:
   a) APPLY
      i) Gather the following:
         - Cover letter indicating how this internship can help you attain your goals and specify the position(s) for which you are applying
         - Resume
         - Academic transcript
         - 3 letters of recommendation including one academic and one work reference
         - Applicants must also complete the University of Pennsylvania's application process. Click here for the appropriate form (link to Penn application)
         - Print out the completed application and mail a signed copy along with the other materials to:

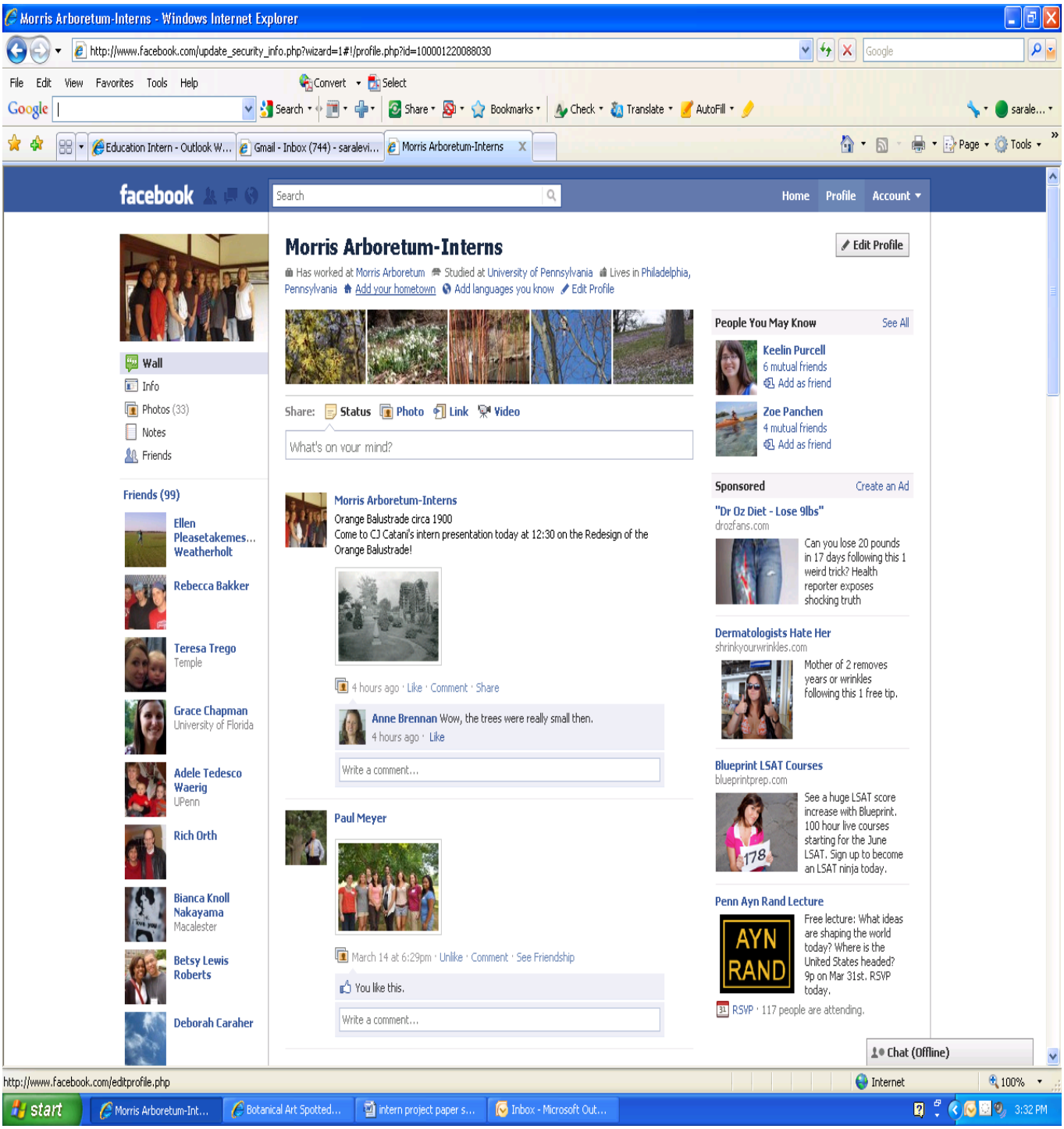
           Jan McFarlan, Education Coordinator
           Morris Arboretum of the University of Pennsylvania
           100 E. Northwestern Ave
           Philadelphia, PA 19118

           International Students are accepted

           Questions? Call Jan McFarlan, Education Coordinator at 215-246-5777 x 156
           Or email at jlm@exchange.upenn.edu

           Applications are must be received by February 15th for the 2011 Internship Program
   b) PICTURE OF GREEN ROOF

APPENDIX F: Facebook Snapshot



APPENDIX G: Tour Page Updates

PLAN YOUR VISIT

GUIDED TOURS

(picture)
1) Field trips
Let nature be your classroom!
Visit the Arboretum with your class, home school group or summer camp!

(picture)
2) All access tours
No reservations needed!
Just show up and enjoy these regularly scheduled tours

(picture)
3) Prearranged tours
Call ahead for a tour that will interest your group!
Discover hidden treasures at the Arboretum!

FIELD TRIPS AT THE ARBORETUM

Choose a tour from the list below then call or email Lisa Bailey at 215-247-5777 x 157 or baileyl@exchange.upenn.edu to make arrangements for your visit!

General Tour (all ages)

Big Trees Tour (all ages)
Seasons and Cycles (K-2)
Tree Adventure Tour I (K-3)
Food Factory (2-3)
Trees Where We Live (3-5)
Calculate and Cultivate (4-6)
Tree Adventure Tour II (4-6)
Plant Reproduction: Seed Formation (5-6)
Plant Reproduction: Seed Dispersal (5-6)
Wetlands Exploration (4-7)
Tu B'Shevat (Pre-K-3)
Arbor Week (K-4)

Click here for a list of PA Department of Education Academic Standards met on our tours! (this links to PAGE 7)

General Tour

All Ages

Explore our 92-acre living museum.
See the tree highlights!
Learn about the Arboretum's history.

Tour Length: 1 hour

PHOTO

Big Trees Tour
All Ages

Morris Arboretum is home to some of the oldest, rarest and largest trees in Philadelphia!
Learn about trees that are native to Pennsylvania and beyond.
Discover the ancient Dawn Redwoods—originally found in North America more than 150 million years ago!
Learn about our state tree, the eastern hemlock.

Tour Length: 1 hour

PHOTO

Seasons and Cycles
Kindergarden-2nd Grade

Take a sensory journey through the Arboretum.
Learn the natural characteristics of each season.
Predict changes that plants will undergo with each season.
Collect plant material to bring home to your classroom!

Teacher's Guide: Pre and Post Visit Guide and Activities [CLICK on "teacher's guide"]

Tour Length: 1 hour

PHOTO

Tree Adventure Tour I
Kindergarden-3rd grade

Learn responsibility from a tree!
Leaves are responsible for producing food.
Bark is responsible for protecting the trunk.
Roots are responsible for absorbing water and storing food.
People are responsible for taking care of trees in their neighborhoods.

Tour Length: I hour

Food Factory
2nd and 3rd Grade

Become the parts of a tree to see how they work.
Study the parts of the amazing leaf.
Move materials along the trunk's transportation system.
Learn why a tree can stand up in a hurricane.

Teacher's Guide: Pre and Post Visit Guide and Activities!

Tour Length: 1 hour

Trees Where We Live
3rd -5th Grade

Southeastern Pennsylvania is an urban forest.
Find out why we need to take care of trees.
Discover how the trees keep us healthy and how we can help the health of the trees!
Learn about the urban forest habitat.
Learn about oxygen and other gifts we get from the trees!

Tour Length: 1 hour

PHOTO:

Calculate and Cultivate
4th-6th Grade

Work in teams to measure garden plots and determine the area.
Use math skills to graph plots and convert inches to feet.
Choose the plants you want to grow.
Compete with other teams and calculate your garden's yield and profit!

Teacher's Guide: Pre and Post Visit Guide and Activities

Tour Length: 2 hours

Tree Adventure Tour II
Grades: 4th-6th

Identify ways in which humans depend on nature for survival.

Understand how and why roots grow.
Learn about photosynthesis.
Learn how soil, water and sun help trees grow.

Teacher's Guide: CLICK HERE for Pre and Post visit guide and activities
Tour Length: 1 hour

Plant Reproduction (Seed Formation)
5th and 6th Grade

Explore the inner workings of a flower and the precision needed to create seeds.
Analyze the structure of a flower and the purpose of its parts.
Predict the pollination method of a plant based on floral characteristics!
Name the benefits of pollination and fertilization.
Describe the process of seed formation.

Teacher's Guide: Click here for Pre and Post visit activities
Tour Length: 1.5 hours

Plant Reproduction (Seed Dispersal)
5th and 6th Grade

Seeds ensure the survival of a species!
Learn where to find seeds.
Uncover how seeds are dispersed into nature.
*Seed dispersal in the Arboretum is best displayed from late summer into the fall.

Teacher's Guide: Click here for Pre and Post visit activities
Tour Length: 1.5 hours

Wetland Exploration
4th -7th Grade

Explore The Morris Arboretum Wetland on foot!
Discover the function of wetlands and why they are so vital to nature.
Observe and record the different plants and animals that thrive in a wetland.
Explain the environmental and economic consequences that can arise with the loss of wetlands.
Brainstorm ways we can help safeguard wetlands for the future!

Tour Length: 1.5 hours
PHOTO of wetlands

Tu B'Shevat

Pre-kindergarten – 3rd grade

Celebrate the Jewish New Year of Trees in late January / early February.
Transplant a native tree seedling to take home and watch it grow.
Play Arboretum Jeopardy®.
Find out why roots are so important to trees.

Reservations are accepted after November 1.

Arbor Week
Kindergarten – 4th grade

Celebrate Arbor Day during the last week of April.
Transplant a native tree seedling to take home and watch it grow.
Play Arboretum Jeopardy®.
Find out why roots are so important to trees.

Pennsylvania Academic Standards

http://www.pacode.com/secure/data/022/chapter4/s4.83.html

2.3 Measurement and Estimation
Trees Where We Live
Calculate and Cultivate
Tree Adventure Tour (4th -6th grade)

2.6 Statistics and Data Analysis
Calculate and Cultivate

3.2 Inquiry and Design
Trees Where We Live
Calculate and Cultivate

3.3 Biological Sciences
General Tour
Big Tree Tour
Seasons and Cycles
Tree Adventure Tour (K-3rd grade)
Plant Reproduction (Seed Formation)
Plant Reproduction (Seed Dispersal)

4.1Watersheds and Wetlands
Understanding Wetlands

4.2 Renewable and Nonrenewable Resources
Plant Reproduction (Seed Formation)
Plant Reproduction (Seed Dispersal)

4.3 Environmental Health
Food Factory
Understanding the Wetlands

4.6 Ecosystems and Their Interactions
General Tour
Big Tree Tour
Tree Adventure Tour (K-3rd grade)
Tree Adventure Tour (4th-6th grade)

4.7 Threatened, Endangered and Extinct Species
Understanding Wetlands

4.8 Humans and the Environment
Trees Where We Live
Tree Adventure I and II

6.3 Scarcity and Choice
Wetlands Tour

All-Access Tours (no reservations needed)

Guided Tours
Every Saturday and Sunday at 2:00

Choose your adventure every Saturday and Sunday at 2 pm! Our knowledgeable guides will design a tour around the interests of the attendees! Every tour is different so come back as many times as you'd like!

Great Trees Tour

Sundays in April, July and October at 1:00

Many trees still remain from the Morris's estate. Come tour the grounds and discover the Great Trees of the Arboretum. Learn about our ancient and unique specimens while hearing a bit of history as you walk.

Click here for a Great Trees Tour map

Winter Wellness Walks

Saturdays November-March at 10:30

Take a brisk walk on the paved paths of the Arboretum. Led by a Volunteer Guide, you'll get your heart rate up in a terrific setting.

Photos

Join us for all tours at no additional payment beyond your entrance fee!

Prearranged Group Tours (call or email for reservations)
Select a Tour from the list below…

Group Rates:

Adult and Family Tours: Adults: 12$
Kids: 6$

Select a tour from the list below:
Seniors: 10$
Outstanding Trees
Garden Highlights
Victorian Garden
Japanese Elements
Winter Walk
Great Plants for Your Home
Art in the Garden
Penn Student Tours (see below**)

New Member Tours

New members of the Morris Arboretum can sign up for a complementary guided tour of the grounds. Book this tour and get to know the Arboretum!

…then make a TOUR RESERVATION (link reservation detail page)
Tour reservations can be made with Lisa Bailey, Education Administrative Assistant at baileyl@exchange.upenn.edu or 215-247-5777 x157…

School Tours and Field Trips:

Click HERE to connect to our FIELD TRIP page!

**Morris Arboretum offers free admission to University of Pennsylvania students. Transportation from Penn's campus to the Arboretum is offered several times a semester. Contact Miriam Pinsker at 215-247-5777 x 281 or mpinsker@upenn.edu

APPENDIX H: Google Analytics

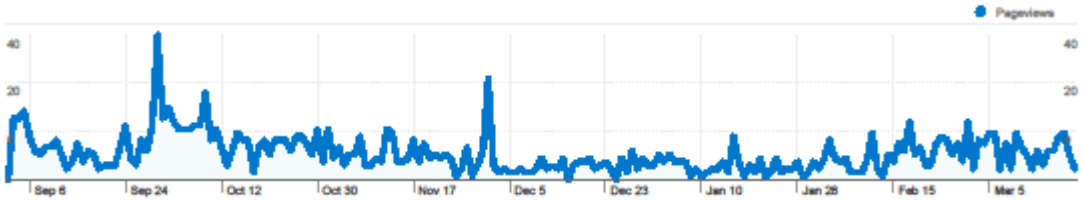
www.morrisarboretum.org

Content Detail:

/arboretum/bloomCalendar.html

Sep 2, 2010 - Mar 21, 2011

Comparing to: Site



This page was viewed 1,464 times

1,464 Pageviews

1,277 Unique Views

00:01:12 Time on Page

52.73% Bounce Rate

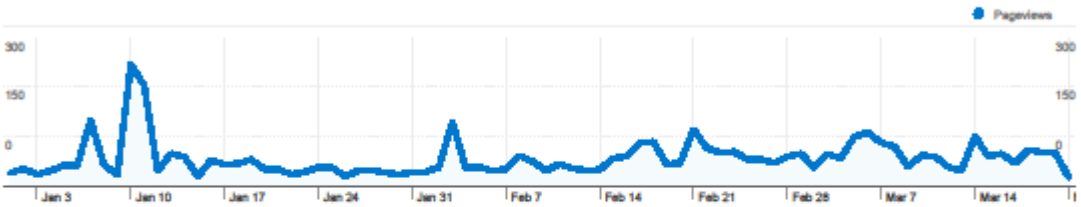
23.57% % Exit

$0.00 $ Index

www.morrisarboretum.org

Top Content

Jan 1, 2011 - Mar 21, 2011
Comparing to: Site



21 pages were viewed a total of 4,489 times

Filtered for pages containing "tour"

Content Performance

Pageviews	Unique Pageviews	Avg. Time on Page	Bounce Rate	% Exit	$ Index
4,489 % of Site Total: 3.13%	3,223 % of Site Total: 3.12%	00:00:33 Site Avg: 00:00:55 (-38.67%)	39.08% Site Avg: 36.62% (6.73%)	11.38% Site Avg: 23.66% (-51.88%)	$0.00 Site Avg: $0.00 (0.00%)

Page	Pageviews	Unique Pageviews	Avg. Time on Page	Bounce Rate	% Exit	$ Index
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/arboretum/visit_tours.shtml	1,186	767	00:00:27	41.89%	11.72%	$0.00
/arboretum/allAccessTours.shtml	680	559	00:00:58	70.42%	24.56%	$0.00
/arboretum/ed_tours_bigtree.shtml	137	79	00:00:55	0.00%	2.92%	$0.00
/arboretum/ed_tours_TAKto3.shtml	120	78	00:00:36	100.00%	15.00%	$0.00
/arboretum/ed_tours_general.shtml	103	79	00:00:19	0.00%	4.85%	$0.00
/arboretum/ed_tours_food.shtml	92	61	00:00:44	87.50%	16.30%	$0.00
/arboretum/ed_tours_seasons.shtml	80	60	00:00:40	33.33%	10.00%	$0.00
/arboretum/ed_tours_cultivate.shtml	79	36	00:00:41	0.00%	6.33%	$0.00
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/arboretum/ed_tours_wherewelive.shtml	35	21	00:00:20	0.00%	2.86%	$0.00

TITLE: **ARBORICULTURE EDUCATION:**
Extending Five Seconds of Curiosity to Five Minutes of Discovery

AUTHOR: **Bryan Thompson-Nowak**
The Walter W. Root Endowed Arboriculture Intern

DATE: **March 2011**

ABSTRACT:

The practice of modern arboriculture is fascinating to some and strikes fear into the hearts of others. Properly caring for trees is both physically and intellectually challenging. The Morris Arboretum has a unique role as both a public garden and a leader of environmental education. For those that are curious about arboriculture the chances to be curious and ask questions are quite limited. Here at the Morris Arboretum we have the unique opportunity to work in the garden while visitors are in attendance. Visitors that understand the Arboretum's role in education readily ask questions and watch the arborists at work. The problem that presents itself is the inability of the arborist(s) to respond to the many inquiries while work is being done. These lost opportunities are the focus of this project. A two sided 2 x 3 feet sandwich board was designed to answer the most basic questions visitors ask. How does an arborist climb a tree? What are the arborists doing in the tree? What type of tree is it? And what type of work are you doing now? These questions are answered in an effort to capitalize on the visitor's curiosity about arboriculture and tree care and give them a spring board for further discovery. The sign is portable, easily set up and informative.

Arboriculture Education:
Extending Five Seconds of Curiosity to Five Minutes of Discovery

TABLE OF CONTENTS

INTRODUCTION

In extending educational opportunities to members and visitors of the Morris Arboretum, capitalizing on teachable moments in the garden is important. A wealth of new visitors to the Arboretum have been drawn to exciting new exhibits like "Out on a Limb" and long-time favorites like the Garden Railway. In our efforts to reach new visitors and long-time visitors alike, we must remember that connecting them with the garden is important. A vibrant, changing and engaging experience will keep visitors interested in both the Arboretum and the environment. The Arboretum does an amazing job with its programs, tours, classes, and social networking outlets. By extending informal arboriculture I hope to add a small element to the many reasons why a visit to the Arboretum is a new experience, where we are "Always Growing."

This project seeks to grow the knowledge and understanding of trees in the environment among the general public, primarily visitors to the Arboretum. Arboriculture in its most basic form is interesting and exciting to watch. Visitors passing by are drawn to watch arborists as they climb trees, trim branches, or lower large limbs. Whether it is out of curiosity or fear, there is a moment when the attention of the visitor is fully captured by an arborist. This moment can be the first step to a greater interest in trees – and hopefully tree care and conservation.

THE NEED FOR ARBORICULTURE EDUCATION

The need for arboriculture education is evident from the many young trees improperly planted with mulch piled too high to mature trees with their root system cut away for new paving or construction projects. I worked for almost ten years in environmental education, and like many nature centers, mine relied heavily on animals to convey the importance of protecting and preserving the environment. Summer camps with animals always filled faster than those without. The challenge for the educators and visitors alike was simply how to get people excited about plants. Our one ace card was the maple sugaring season, when the sweet sap and warm campfires drew visitors close to trees. The importance of trees and their preservation became even more important to me during the years I spent in Haiti; this experience was instrumental for me to realize what a world looked like without trees and without a strong connection between humans and trees. Coming to the Morris Arboretum and seeing visitors curiously and cautiously watching arborists at work in a tree – when only moments before their only concern was finding their position on a map – awakened the educator in me. I made myself available to these visitors and found they often asked many questions. Disappointingly, many opportunities to interact with visitors were lost, as the need to assist a climber or clear fallen limbs was more important than continuing a conversation. These lost opportunities to build on a visitor's curiosity seemed important and drove me to seek a way to engage these visitors and try to create a unique learning experience.

Tree care and preservation are topics that should interest everyone, but unfortunately they do not. The loss of a tree has many residual impacts, including loss of wildlife habitat, decreased absorption of water, reduced air quality – not to mention the negative effects on property value.

Unlike many things in our society, a mature tree cannot be easily replaced. The understanding that people can have an active role in preserving trees is one that needs to be spread. It seems that many people mistakenly "let mother nature take its course" with trees, and when a tree becomes a problem to the homeowner it is removed. I would like to make inroads to the general public to show them that tree care is something that is not impossible and when done properly can benefit the tree as well as the property owner.

THE TEACHABLE MOMENT

A simple concept in education provides the foundation for those unique moments when an arborist is working in a tree and a visitor's attention and interest are obtained. This moment is a teachable moment, and is defined as "the time at which learning a particular topic or idea becomes possible or easiest." This concept was popularized by Robert Havighurst in his 1952 book, *Human Development and Education.* In the context of education theory, Havighurst explains, "A developmental task is a task which is learned at a specific point and which makes achievement of succeeding tasks possible. When the timing is right, the ability to learn a particular task will be possible. This is referred to as a 'teachable moment.' It is important to keep in mind that unless the time is right, learning will not occur. Hence, it is important to repeat important points whenever possible so that when a student's teachable moment occurs, s/he can benefit from the knowledge." The phrase sometimes denotes not a developmental stage but rather "that moment when a unique, high interest situation arises that lends itself to discussion of a particular topic." It implies "personal engagement" with issues and problems.

This concept is used throughout the Arboretum. "Out on a Limb" capitalizes on the excitement of being in the tree tops to educate visitors about the sprouting of a seed and life of a tree. In the parking lot we inform visitors of the permeable macadam beneath their feet. As people are enjoying their walk through the Oak Allee, roots painted on the macadam draw visitors' eyes down to signage explaining how roots function.

These "unique high interest situations" are ones that we cannot let pass us by; they are opportunities for discovery and understanding that will connect the visitor more deeply with the environment and the Arboretum.

TARGET AUDIENCE

The types of visitors and members of the Arboretum vary widely from school children to public garden enthusiasts, home gardeners, nature lovers, as well as those interested in Asian flora. When deciding who the target audience will be, I took notice of who most of the people were asking me questions (as well as the style of educational material already displayed in the garden). Taking cues from "Out on a Limb," I wanted to keep the material simple and concise and include some interactive elements. The target visitor(s) I envisioned for the project are those that have little to no experience with horticulture and perhaps are visiting with children.

DESIRED IMPACT OF SIGNAGE

The expected primary outcome is a more informed and enriched visit to the garden. Secondarily, I hope this will impress the importance of tree care upon visitors and leave them more informed about trees and tree care. I also hope they will come to the understanding that, when faced with caring for trees on their own property, a higher level of care can be given. The ideal scenario would involve a visitor with a large shade tree on his or her property and has not thought to investigate the health of the tree. Now, after watching (and better understanding) tree maintenance at the Arboretum, that visitor is made aware of a dangerous defect in a tree, over mulched trees or weed-whacker damage in one of their own trees and can take steps to address these problems. Essentially, an increased sense of responsibility and care towards trees is the goal.

FORMAT/FOUNDATION AND DEVELOPMENT STAGES OF THE SIGN

Why a sandwich board?

When deciding how to engage the visitor, several things needed to be taken into account. First I considered how to physically place something in the garden near the arborist work zone. The smallest and most portable option is a set of sandwich boards (already commonly used by the Arboretum). Ideas for larger displays included a sign board attached to the arborists' trailer, or a larger interactive display inside that trailer. These options require less set-up time and would be larger and potentially more engaging. However, both of these options require the trailer to be used in the garden during every work day, which does not currently happen. After much consideration we decided to create a sandwich board. Considering size, portability and cost, a sandwich board was considered the best available option. A sandwich board can be easily transported in a truck, is large enough for visitors to see, and is easy to set up. A limitation of the sign is the need to physically transport and set up the sandwich board at each work site.

METHODS FOR DECIDING EDUCATIONAL TOPICS

With the format decided, the content of the sign was still open. Suggestions included types of arborist knots, types of trees, tree biology, soil and root interactions, a pruning how-to, life stages of a tree, felling a tree, arborist equipment, chainsaw use, and general care & maintenance. These were all good suggestions, but we needed a method to discover what visitors are interested in. Visitors, not Arboretum staff or arborists, are the target audience, and their interests are ultimately what should drive the content of the sign.

A period of two weeks was set aside for visitor research during climbing tree work in the garden. During these two weeks, volunteers and guides were located on the main pathways near the work site. These volunteers engaged visitors as they passed by, answered questions, and explained what work was being done and why. Notes were taken after each interaction to gauge

the level of interest in various aspects of arboriculture. Our hope was that as volunteers took notes of the questions asked by visitors, a trend would emerge of main topics of interest.

Ultimately one day's worth of visitor information was gathered (unfortunately the timing, weather, season and volunteer availability limited the amount of data collected). The one day of data collecting provided responses from approximately ten visitors that ranged from 2 adult members on their daily walk and a class of fifth graders to a visitor with her five-year-old grandson. Perhaps not surprisingly, the main question was simply "What are they doing?" The second most-common questions revolved around how the work was being done. Despite the disappointingly low amount of visitor information acquired during the formal research, follow-up talks with education department staff and impromptu talks with visitors solidified that these two basic questions were engaging enough to pursue. Thus the signs will answer the questions, "How do you get up there?" and "Why are you up there?"

EXPLANATION OF IMAGES

With a simple, concise, informative sign as my goal, I decided to have a central image and text to explain the image. Deciding how to make the images presented some challenges. For example, depicting how an arborist climbs a tree in The Tree Climber's Companion is done solely with drawn illustrations. This popular book uses several images and pages of text to describe the act of climbing a tree safely. Faced with my own limited illustration skills, I decided to rely on photography as my primary method to illustrate how and why arborists care for trees A collection of photos was taken at the Arboretum, as well as area shopping centers, housing developments, and town parks. From this collection I chose several images I wanted to include in the sign.

The "how" side was initially composed of 4 to 5 images showing the steps taken to enter a tree and move about in it. After several discussions with Arboretum staff, the need to simplify the sign and reduce the number of images became apparent. The need to display multiple images while limiting myself to one image posed a problem. However, I was able to use Photoshop to insert all of the steps of tree climbing into one image. The end result for the "how" side is a single diagram composed of eleven separate images. I also used Photoshop on the "why" side to consolidate multiple defects in only two trees and to erase parts of the background that seemed distracting. The end result is a set of clean images that clearly convey the fundamental ideas.

EXPLANATION OF TEXT

The body of text that accompanies the images needed to be as equally clear and concise as the photos. The body of terms that arborists use is similar to that of any profession, with some terms being intuitive and some being very technical. For example, main tree stems are called "leaders." An arborist can "subordinate a co-dominant leader," which means to cut back a leader so that is it smaller and subordinate to a larger leader. Most casual visitors to the Arboretum are not well-versed in the arborist lexicon and the signs needed to use a simpler vocabulary. I started by writing out 4 steps to climb a tree with 2 to 5 sentences per step and ended up trimming the

text to 1 to 2 sentences per step. The first draft had about 240 words, and the final copy trimmed about 100 words from the original. It is very important, from my point of view, that non-arborists are able to read and understand the text without getting bogged down or bored with it.

INTERACTIVE ELEMENT

The final, interactive element of the sign is the incorporation of a section of rope and a friction hitch. This type of knot holds everything together in an arborist's climbing system, and understanding how it works is very helpful to understanding how the entire system works. Also, this knot is an active element that kids and adults can touch and interact with. The goal of this is for people to both have fun and also try to figure out how the knot functions. The other element of the sign is a small whiteboard section where the arborist can write the name of the tree and type of work being done at that time in order to specifically address the common questions that visitors have.

EDITING PROCESS

After the images and text were deemed acceptable, a preliminary layout was done and given to various Arboretum staff members for comments and advice. Appropriate changes were made, and ultimately the Web Manager Zac Brooks added the logo and web address, streamlined the layout, and cleaned up the rough edges to make it suitable for use in the garden.

GUIDE INVOLVEMENT

A presentation was made to the guides to make them aware of the sign and to make it available to them as an educational tool while they are leading tours. From now on when they hear or see the arborists at work in the garden, they can rely upon this sign to be displayed and can use it to help visitors understand the process of arboriculture.

STILL IN PROGRESS

During the coming months I hope to gauge the reaction of the sign through informal talks with guides to see if the sign has been a help to them as they give group tours. Adjustments can be made as to where the sign can be placed, more coordination with the education department as to where work is being done or considerations for improvements to the current or future signs.
In another effort to extend arboriculture education to visitors, I hope to add several elements to the online intern information page to showcase the arborist intern position. A video displaying the type of work the arborist intern does will give potential interns a greater understanding of both the internship and the field of arboriculture.

FUTURE CONSIDERATIONS

The content of the sign and the arboriculture page can be changed and updated. Depending on the interests of the chief arborist and intern, the possibilities for an expanded educational display still hold great potential for visitor education. As recommended by my supervisor, much of the equipment we use can be made available for visitors to explore further (like climbing saddles and rope). If the current signs become dated or interest in another aspect of arboriculture increases, additional signs can be made to replace or augment the current signs. We already have a wealth of information to draw from, including the topics that have been researched by past interns (ranging from the care of mature trees to Hemlock Wooly Adelgid and Emerald Ash Borer). A whole host of topics can be covered while using the same basic principle: visitor curiosity is piqued when someone is working in a tree, and the Morris Arboretum can and should capitalize on that moment to share useful and interesting information about trees and tree care.

CONCLUSION

A previously unexploited educational opportunity for visitors has been addressed. A simple effective arboriculture education display exposes visitors to a new experience at the Arboretum. Individual visitors as well as guided groups can understand more fully what it is arborists do and why it is important.

ACKNOWLEDGEMENTS

Many thanks to Andrew Hawkes, Liza Hawley, Lisa Bailey, Sara Levin, Zac Brooks, Jan McFarlan and Sharon Thompson-Nowak for their help and advice.

REFERENCES

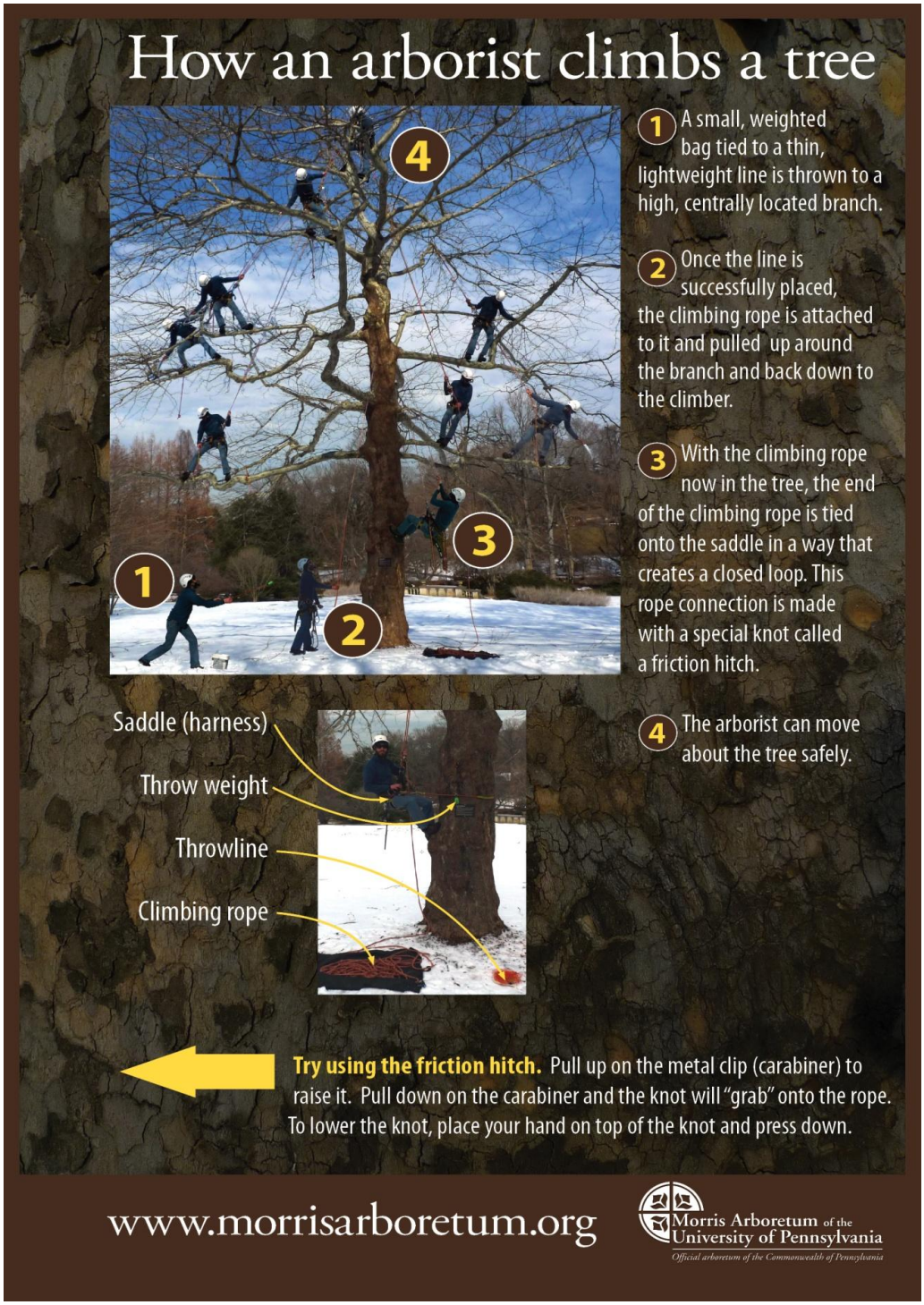
Gilman, Edward F. 1997. An Illustrated Guide to Pruning. Delmar Publishers, Albany, NY.

Jepson, Jeff. 2000. The Tree Climbers Companion. Beaver Tree Publishing, Longville, MN.

Raleigh, Duane. 1998. Knots & Ropes for climbers. Stackpole Books, Mechanicsburg, PA.

Watson, Gary W. and Neely, Dan. 1993. The Landscape Below Ground. International Society of Arboriculture, Savoy, IL.

APPENDIX A: How an Arborist Climbs a Tree



What type of tree is this?

Common name:

Scientific name:

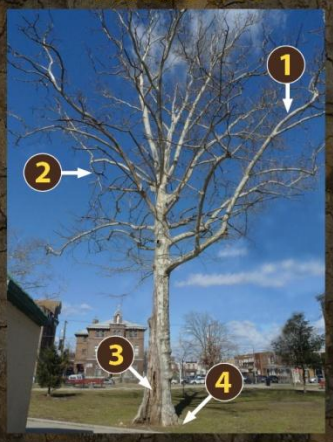
What work are the arborists doing?

Can you see the work that needs to be done in the two trees below?

Young Tree

1. A broken branch needs to be removed.
2. This tree has two central branches that, if left alone, will result in "co-dominant" stems. When large they have a much greater chance of breaking. An arborist will choose a "dominant leader" and prune the other to reduce the risk of breaking.
3. This wound in the tree is most likely from a weed wacker. Wounds can become entrance points for insects, bacteria or fungus that can lead to decay inside the tree.
4. Too much mulch piled at the base of the tree can cause many problems. The mulch should not touch the trunk. The level of the soil should be where the trunk begins to "flare" at its base.

Mature Tree



1. Old long branches need to be pruned to reduce weight and minimize the chance of failure.
2. A broken, hanging limb needs to be removed.
3. A wound at the base of the tree is a sign of internal decay. A qualified arborist should be consulted to examine the extent of decay in the tree.
4. Grass is planted up to the base of the tree which increases the chance of mower and weed wacker damage to the trunk and root system. Two to three inches of mulch under the tree will protect the trunk and roots from future damage and add valuable nutrients to the soil.

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TITLE: **TRACKING TRENDS IN POLLINATION RATES OVER TIME USING HERBARIUM SPECIMENS OF *ASCLEPIAS SYRIACA* (COMMON MILKWEED)**

AUTHOR: **Teresa A. Trego**
The Eli Kirk Price Endowed Flora of Pennsylvania Intern

DATE: **May 2011**

ABSTRACT:

The decline of pollinators and its potential effect on pollination service is a growing concern. The examination of herbarium specimens has proven effective in tracking pollination rates over time for certain plant species. *Asclepias* (milkweed) species require insect pollinators, and their pollen is packaged into pollinia whose removal and deposition can be readily observed in the flowers of herbarium specimens.

We investigated if there was a decline in pollination rates over time in *Asclepias syriaca* (common milkweed) by scoring the removal and deposition of pollinia for 20 flowers from each of 27 historical (collected 1862-1965) specimens and 29 recent (collected in 2009) herbarium specimens from five counties in southeastern Pennsylvania. The mean rates for pollinia deposition (0.32 ± 0.23 SD historical vs. 0.39 ± 0.32 SD recent pollinia per guiderail) were not statistically significant based on Student's T-test. The removal of pollinaria (pollinia pairs) (0.40 ± 0.24 SD historical vs.0.55 ± 0.23 SD recent pollinaria per guiderail) was significantly higher in recent specimens, but not after controlling for flower age.

In conclusion, no evidence for a decline in pollination rates or shift in pollinator visitation over time could be detected in the southeastern Pennsylvania counties.

Tracking Trends in Pollination Rates over Time Using Herbarium Specimens of Asclepias syriaca (common milkweed)

TABLE OF CONTENTS

INTRODUCTION

Pollinator services account for the reproduction of approximately 75% of all angiosperms (National Research Council, 2007). Many wild plants and agricultural crops such as rosaceous plants (apple, pear, cherry, plum, almond) and Arabica coffee are pollinator dependant for fruit and seed set (Biesmeijer et al., 2006; Ghazoul, 2005). Pollinator services in the United States have been valued at US$1.25 billion annually (Ghazoul, 2005). In North America, evidence of decline for the domesticated honey bee (*Apis mellifera*) has been most compelling (National Research Council, 2007). In the United States, there have been reported declines in 1947-1972, 1989-1996, and a recent drop in 2005 for managed honey bee colonies (National Research Council, 2007). A decline in pollinator populations could result in declining pollination services to pollinator dependent plants (Ashman et al., 2004). To date, however, few studies have documented a decline in pollination rates in conjunction with declines in pollinating species (Beismeijer, 2006; Pauw et al., 2010).

Biesmeijer et al. (2006) found parallel declines in bee and hover-fly assemblages and pollinator dependent plant species. Their data indicated that specialized pollinator species with narrower habitat, dietary, migratory, and developmental requirements had greater decline on average than generalist pollinator species. Their study suggested that shifts in pollinator traits such as these could lead to possible shifts in pollination services. They did not find a correlation between pollinator visitation and pollen deposition. However, shifts in plant species distribution were observed using floral inventories to see if declines in plant populations were correlated with declines in pollinator populations.

In Britain, Biesmeijer et al. (2006) found plants reliant on insect pollinators were declining on average while plants reliant on wind or water pollination were increasing. In the Netherlands, plants that were bee pollinator dependent had declined on average while plants pollinated by a wider range of pollinators had increased. Their results showed pollinator dependent plants and specialist pollinator species were declining in tandem. However, their data could not distinguish among the following alternatives: 1) plant declines preceded pollinator decline, 2) pollinator declines resulted in a loss of plant reproductive function leading to a decline in plant populations, or 3) shifts in plant and pollinator populations were responding to some other factor.

Pauw and Hawkins (2010) found parallel declines in pollination rates and populations of a South African orchid species *Pterygodium catholicum* through the comparison of historical (pre-1950) herbarium specimens to recent (post-1950) plant populations. *Pterygodium catholicum* depend heavily on the oil-collecting bee, *Redivia peringueyi*, for seed set and therefore capsule set directly relates to pollination rates across a full range of variability from 0-98% (Pearson's $r = 0.99$, $p < 0.001$, $n = 15$ sites, slope = 1.0) (Pauw, 2007). They found that in areas where the pollinator was absent, capsule set failed completely but where pollinator populations were abundant, higher levels of capsule set occurred.

Pauwand Hawkins (2010) detected shifts in pollination rates and populations of orchid assemblages over time and found pollination rates were higher in historical (pre- 1950)

specimens compared to recent (post-1950) pollination rates. They also showed that in urban communities where pollinator populations were less abundant, orchid assemblages were shifting to clonal species, indicating species reliant on seed propagation were declining. The examination of historical (pre- 1950) *Pterygodium catholicum* herbarium specimens therefore indicated a decline in the non-clonal orchid populations resulted from a decline in orchid pollination rates.

Here we examined 27 historical (collected 1862-1965) and 29 recent (collected in 2009) herbarium specimens of *Asclepias syriaca*, (common milkweed), from five counties in south-eastern Pennsylvania to determine if a change in pollination rates over time could be detected. Like orchids, A*sclepias* species have their pollen packaged into pollinia whose deposition and removal are detectable under a dissecting microscope. *Asclepias syriaca* is dependent on insect pollinators and is most frequently pollinated by generalist species such as, *Bombus griseocolllis* and the European honeybee, *Apis mellifera* (Kephart 1983; Kephart et al., 2003). We hypothesized that a decline in *Asclepias syriaca* pollination rates over time would correlate to a decline in the pollinator population. Herbarium specimens provide a historical record of pollination rates over time and provide consistency for the comparison of pollination rates in historical verse recent specimens.

Asclepias syriaca is in the Apocynaceae family. It has a wide range throughout North America and is commonly found in fields, along roadsides, disturbed soils, and waste grounds (USDA 2011; Rhoads & Block, 2007). According to Rhoads & Block (2007), *Asclepias syriaca* is an herbaceous perennial with erect, simple, stems, 1-2 m tall. It has opposite, oblong-lanceolate to oval leaves. It produces several umbels that are terminal and in the upper axils. It is many-flowered with a deeply divided pink-purple corolla with reflexed lobes.

Its corona consists of five prominent scoop-shaped hoods arising from near the top of the filament column with shorter horns extending from the hoods. The anthers of *A. syriaca* have a triangular appendage at the tip with erect follicles. An *Asclepias* pollinarium consists of a pair of pollinia, each attached to a translator arm that are connected by a corpusculum or "clip" (Kephart & Theiss, 2003). One pollinium develops per anther locule. The "clip" of each pollinarium can be seen with the naked eye and is situated above each of the five anther margins.

Asclepias syriaca flowering extends from June to August with flowering periods around two weeks (Kephart et al., 2003, Kephart, 1987). Most flowers are open 4-6 days with the first and and last flowers to open within each umbel opening within one day of each other in 70% of umbels (Kephart, 1987). The mean umbel size consists of 104 flowers (Kephart, 1987). Flowers in umbels produced earlier in the year remain open slightly longer than flowers in umbels produced later in the season (Kephart, 1987). The fruit develops into 3-4 inch follicles, splitting along one side to disperse its many comose seeds.

As a pollinator visits an *Asclepias syriaca* flower, the anther margin "guiderails" serve to guide an insect's appendage through the central portion of the guiderail and under the "clip" of the pollinarium (Theiss, et al., 2007, Kephart & Theiss, 2003). The insect's appendage is hooked under the "clip" and lifts the pollinarium from the anthers as it moves around or away from the

flower (Theiss, et al., 2007, Kephart & Theiss, 2003). As the insect travels around the flower or to other flowers, the anther guiderails serve to trap the pollinia within the anther margins. An insect can collect a "chain" of pollinaria via attachment of pollinaria to each other on the insect's appendages. Fertilization is then initiated once a pollinium is trapped within the anther margins.

METHODS

Field measurements of pedicel elongation during post-anthesis flower development

Five *Asclepias syriaca* flowers from each of five inflorescences were measured daily from bud to senescence for pedicel length and flower/inflorescence developmental stage. Buds on each inflorescence were individually marked with a different color paint marker on the pedicel and the pedicels were re-measured daily from June 30, 2010 to July 19, 2010. The sampling site was located at Lemon Hill in Fairmount Park, Philadelphia, Pa.

Pollination rates of herbarium specimens

Twenty-seven historical (1862-1965) and twenty-nine recent (2009) herbarium specimens were examined from Chester, Philadelphia, Northampton, Montgomery, and Bucks counties in southeastern Pennsylvania. The historical specimens were collected by various collectors from May to August and made available for this study courtesy of the Academy of Natural Sciences herbarium (PH). The recent specimens were collected by the Ann F. Rhoads, Timothy A. Block, and Lauren Spitz from June to August, 2009 and donated to PH by the Morris Arboretum herbarium (MOOR). The specimens were curated, databased, and scanned. Mention how you compared the distribution of specimen collection dates relative to the flowering season here (i.e. Fig 7).

Twenty flowers per specimen (from one to two inflorescences) were rehydrated *in situ* with damp Kimwipes® and examined *in situ* with a dissecting microscope. When a specimen had multiple inflorescences, the one or two inflorescences with the largest number of flowers at anthesis were selected. A total of 1,120 flowers were scored. For each flower, two to four anther margins "guiderails" were examined For each guiderail, the absence or presence of the pollinarium "clip" was recorded (absence=removal of the pollinarium by a pollinator). The number of pollinia deposited within each anther margin guiderails (0-3 pollinia deposited by a pollinator) was also recorded.

Pedicel lengths were digitally measured from the jpeg image using ImageJ for five of the twenty flowers scored from each specimen to control for flower age. Student's T-test was used to test the significance of the difference between the historical (1862-1965) and recent (2009) specimens of three response variables: pollinia deposition, clip removal, and pedicel length. Significance was accepted at p=0.05.

For each specimen, the average rate of pollinium deposition per guiderail was calculated by dividing the sum of pollinia deposited in all 20 flowers by the sum of all guiderails scored.

Likewise, the average rate of clip removal per guiderail was calculated for each specimen by dividing the sum of clips removed from all 20 flowers by the sum of all guiderails scored. The average pedicel length for each specimen was calculated for the five pedicels measured. A linear regression using pedicel length as the predictor variable and clip removal as the response variable was used to control for effect of flower age on pollination. A T-test of the residuals was used to determine if specimen age (historical versus recent) explains any additional variation not explained by flower age.

RESULTS

The field data for pedicel length measurements and flower development resulted in a correlation between pedicel length and flower development. The flower pedicel length showed to increase with flower age. The means for pedicel lengths (mm) from day one to day six are listed respectively: 23.8mm ± 3.56 SD, 25.3mm ± 3.55 SD, 26.6mm ± 3.31 SD, 27.8mm ± 4.08 SD, 28.2mm ± 4.00 SD, 30.3mm ± 4.03 SD. The average rate of elongation per day (the mean difference between pedicel lengths measured repeatedly on successive days) was 1.1mm. (See Fig. 1.)

The comparison of collection days after June 1st for the historical (1862-1965) and recent (2009) specimens resulted in the means, (37.0 ± 11.9 SD historical vs. 38.9 ± 11.9 SD recent). This difference was not significant based on Student's T-test (t= - 0.57, p = 0.57). (See Fig. 2.) The means for pollinia deposition in historical (1862-1965) vs. recent (2009) specimens resulted in (0.32 ± 0.23 SD historical vs. 0.39 ± 0.32 SD recent pollinia per guiderail). Pollinia deposition was greater in recent specimens but was not statistically significant based on Student's T-test (t= -0.96 and p= 0.34) (See Fig. 3.). The removal of clips (0.40 ± 0.24 SD historical vs. 0.55 ± 0.23 SD recent pollinia per guiderail) were higher in recent than in historical specimens and significant (t= -2.44, p=0.02) (See Fig. 4.).

The average pedicel length (2.56 ± 0.45 SD historical vs. 2.84 ± 0.31SD recent) were higher in recent than in historical specimens and also significant (t= -2.71, p=0.01) (See Fig. 5.) The regression of pollinia removed per guiderail against average pedicel length resulted in a significant and positive but weak correlation (r=0.41, p=0.002) (See Fig. 6.). After controlling for pedicel length, the residual of pollinia removed per guiderail (-0.04 ± 0.20 SD historical vs. 0.04 ± 0.20 SD recent) was not significantly different between the two groups (t= -1.42, p=0.16) (See Fig. 7.).

DISCUSSION

Flower age (Fig. 1) but not date of collection (Fig. 2) proved to be significantly different between the historical and recent specimens. Since the collectors of the recent (2009) specimens were collecting specifically for a pollination study while the collectors of the historical specimens were not, collector bias in the recent specimens is most likely the cause for the older flowers in that group. Accounting for flower age indirectly, by controlling for pedicel length,

eliminated the significant effect of this bias in our comparisons, resulting in no significant difference in pollination rates (deposition and removal) over time (Fig. 7.).

Our field data showed that pedicels elongate by an average of 1 mm per day from day 1 to day 5 of anthesis (Fig. 1.) validates the use of pedicel length as an indirect measure of flower age and pollinator exposure. Our sample for measuring the rate of pedicel elongation with flower age is limited (only one population, possible all one clone) so we don't know how precisely pedicel length predicts flower age. The correlation between flower maturity and pedicel lengths in herbarium specimens, (Fig. 5.) could be used in comparison to collection time to study phenological response to climate change over time. This area of research needs to be considered further.

No change detected in pollination rates over time indicates that no change can be detected in the total quantity of pollination service, but this does not demonstrate a change in the pollinator community. It is not possible to determine which specific pollinator species are thriving and which are declining through the observation of pollination rates alone. A comparison of the pollinator communities visiting *Asclepias syriaca* today to those recorded in past pollination studies (Kephart, 1983; Theiss, et al., 2007) may yield evidence for change in the composition of the current community.

Another avenue of research that may be pursued is the expansion of this herbarium-based method to a wider geographic range and species diversity of *Asclepias*. Perhaps the apparent stability of pollination rates we observed is particular to southeastern Pennsylvania. Pollination rates measured from herbarium specimens of rare or endangered *Asclepias* species may detect evidence of declining pollination rates over time, a potential contributing factor to the decline and displacement of species of concern (Pauw & Hawkins, 2010). In combination with pollination studies on living populations, the examination of pollination rates in herbarium specimens on a wider scale could add an important temporal dimension to the understanding of pollination change and statis.

CONCLUSION

The examination of *Asclepias syriaca* herbarium specimens proved effective for detecting historical pollination rates. No significant difference was found for pollinia deposition between historical and recent specimens. A significant difference in pollinaria removal between historical and recent specimens was detected but this was accounted for by a difference in flower age. No significant difference between the two groups resulted after factoring out flower age. Therefore, no evidence for change in pollination rates over time or for any decline or shift in pollinator visitation on *Asclepias syriaca* was detected in the southeastern Pennsylvania herbarium specimens.

FIGURES

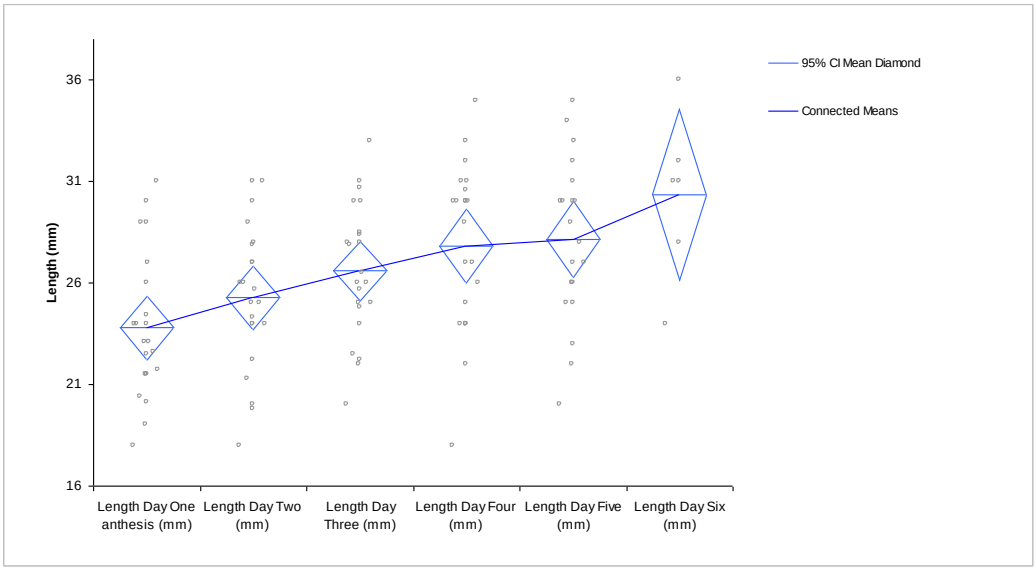

Fig. 1. Field pedicel length measurements

Elongation of individual *Aclepias syriaca* pedicels identified by inflorescence number and flower color, measured in mm (y-axis) from day 1 to day 6 of first marked flower in observed in anthesis (x-axis) based on field measurements. The means for pedicel lengths (mm) from day one to day six are listed respectively: (23.8mm ± 3.56 SD, 25.3mm ± 3.55 SD, 26.6mm ± 3.31 SD, 27.8mm ± 4.08 SD, 28.2mm ± 4.00 SD, 30.3mm ± 4.03 SD). The average rate of elongation per day (the mean difference between pedicel lengths measured repeatedly on successive days) was 1.1mm.

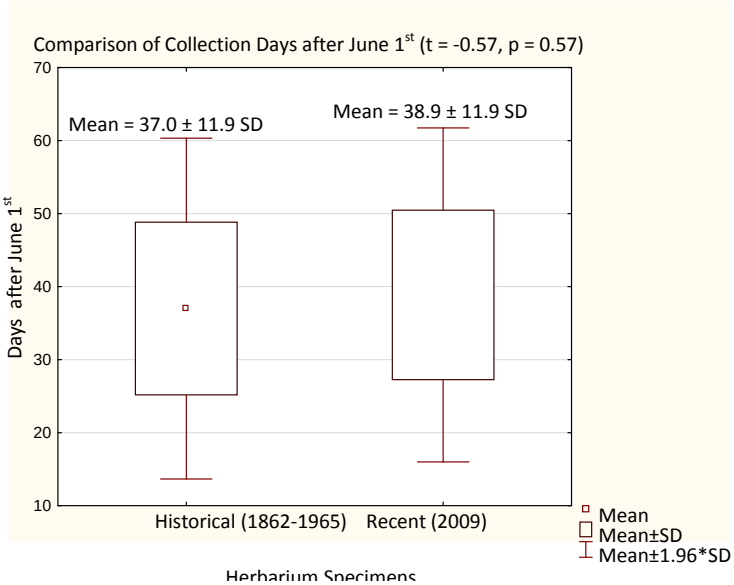

Fig. 2. Comparison of collection dates per specimen
Box graph comparing the collection times (measured as days since June 1) between historical (1862-1965) and recent (2009) specimens. The means were (37.0 ± 11.9 SD historical and 38.9 ± 11.9 SD recent) but were not significant based on Student's T-test (t = -0.57, p = 0.57).

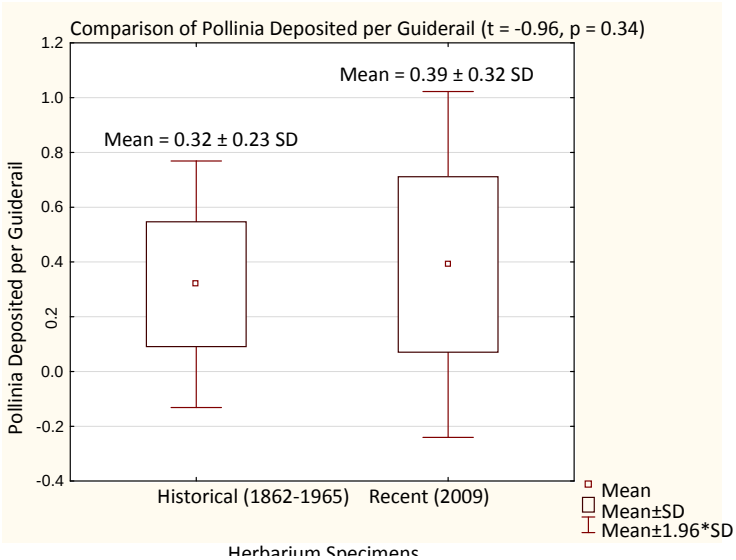

Fig. 3. Comparison of average rates for pollinia deposition per specimen
Box plot comparing the average rate of pollinium deposition per guiderail (sum of pollinia deposited for each specimen/ sum of guiderails scored per specimens). The means, 0.32 ± 0.23 SD historical versus. 0.39 ± 0.32 SD recent pollinia per guiderail, were not significantly different based on Student's T-test (t= -0.96 p= 0.34).

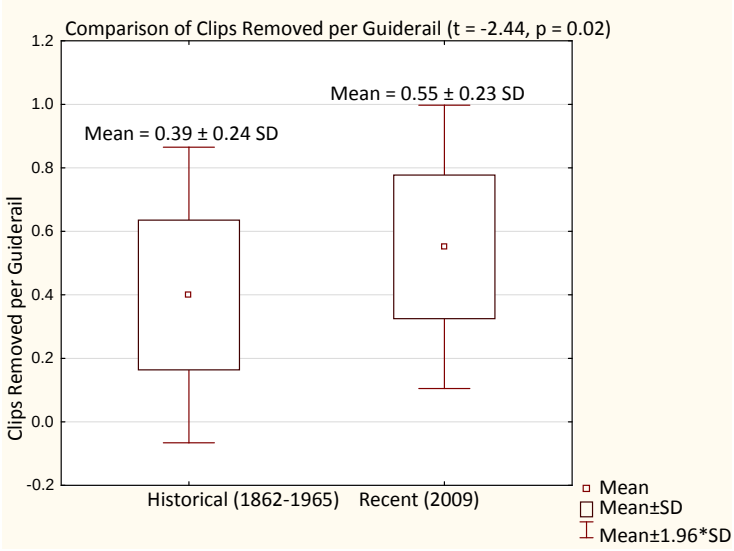

Fig. 4. Comparison of average rates for clips removed per specimen
Box graph comparing the average rate of clips removed per guiderail (sum of clips removed for each specimen/ sum of guiderails scored per specimen). The removal of pollinaria (0.39 ± 0.24 SD historical vs. 0.55 ± 0.23 SD recent pollinaria per guiderail) were higher in recent than in historical specimens, and the difference is significant (t= -2.44, p=0.02).

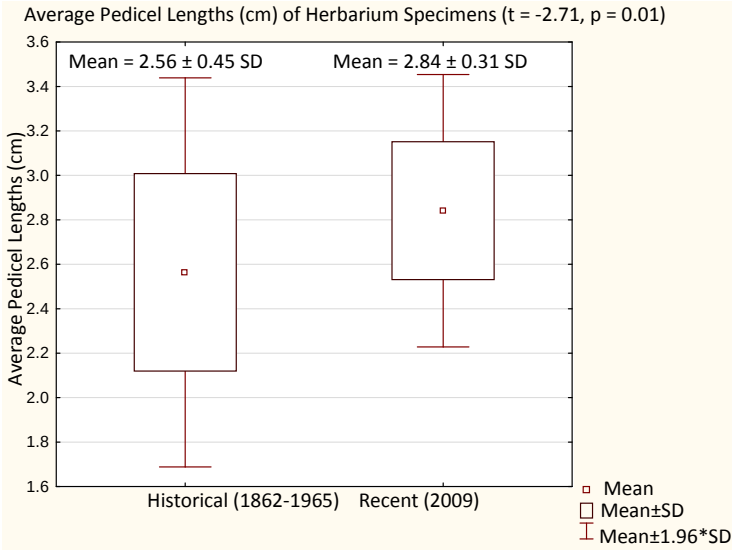

Fig. 5. Comparison of average pedicel lengths per specimen
Box graph comparing the average pedicel lengths (cm) for historical (1862- 1965) and recent (2009) herbarium specimens. Pedicel lengths were digitally measured for five of the twenty flowers scored from each specimen to control for flower age. The average pedicel length equaled the average of five flower pedicel lengths per specimen and the difference between the two groups is significant (t = -2.71, p = 0.01).

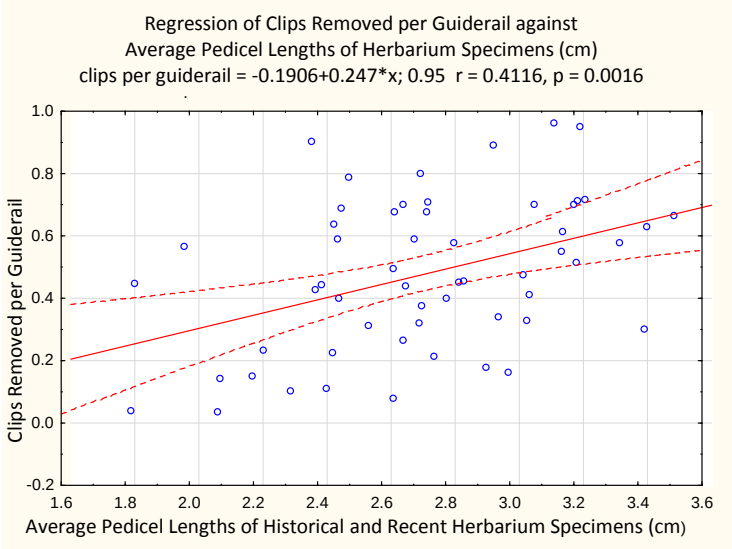

Fig. 6. Linear regression of clips removed per guiderail against pedicel length
The regression of clips removed per guiderail against average pedicel length showing a significant and positive but weak correlation (r = 0.41, p = 0.002). Herbarium specimens are represented by the blue dots and the regression line by the solid red line.

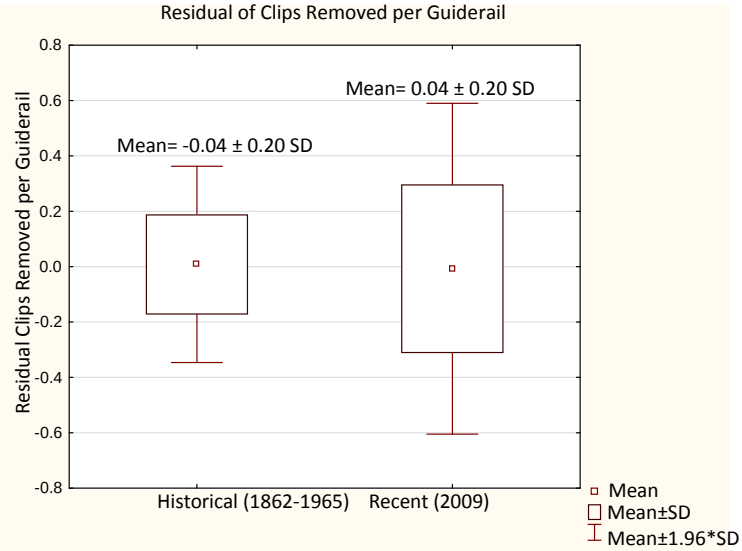

Fig. 7. Average residual rate of clips removed per specimen
Box graph comparing the residual for the average rate of clips removed per guiderail (-0.04 ± 0.20 SD historical vs. 0.04 ± 0.20 SD recent) resulting in no significant difference between the two groups (t= -1.42, p=0.16).

REFERENCES

Ashman, T. et al., 2004. "Pollen limitation of plant reproduction: ecological and evolutionary causes and consequences." Ecology. 85(9): 2408-2421.

Biesmeijer, J.C. et al. 2006. "Parallel Declines in pollinators and Insect-Pollinated Plants in Britain and the Netherlands." Science 313: 351-353.

Buchman, S. and Nabhan, G. 1996. The Forgotten Pollinators, Island Press.

Ghazoul, J. 2005. "Buzziness as usual? Questioning the global pollination crisis." Trends in Ecology and Evolution, Vol. 20 No. 7, 367-373. Committee on the Status of Pollinators in North America, National Research Council. 2007. "Status of Pollinators in North America." http://www.nap.edu/catalog/11761.html

Kephart, S. 1981. "Breeding systems in *Asclepias incarnata* L., *A. syriaca* L., and *A. verticillata* L." Amer. J. Bot. 68 (2): 226-232.

Kephart, S. 1983. "The partitioning of pollinators among three species of Asclepias." Ecology. 64(1): 120-133.

Kephart, S. 1987. "Phenological variation in flowering and fruiting of Asclepias." The American Midland Naturalist. 118:64-76.

Kephart, S. and Theiss, K. 2003. "Pollinator-mediated isolation in sympatric milkweeds (Asclepias): do floral morphology and insect behavior influences species boundaries?" New Phytologist 161: 265-277.

Pauw, A. and Hawkins, J.A. 2010. "Reconstruction of historical pollination rates reveals linked declines of pollinators and plants." Nordic Society Oikos. 1-6.

Theiss, K., Kephart, S., Ivey, C. T. 2007. "Pollinator effectiveness on co-occuring milkweeds (Asclepias; Apocynaceae, Asclepiadoideae)." Ann. Missouri Bot. Gard. 94: 505-516.

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Tatyana Livshultz, The Academy of Natural Sciences, Philadelphia, PA.

Dr. Timothy A. Block and Dr. Ann F. Rhoads, The Morris Arboretum of the University of Pennsylvania, Philadelphia, PA.

TITLE: **SACRED SITES OF THE MORRIS ARBORETUM**

AUTHOR: **Shea A. Zwerver**
The Charles S. Holman Rose and Flower Garden Intern

DATE : **APRIL 2011**

ABSTRACT:

This research project is designed to measure stakeholder's "sacred" sites of the Morris Arboretum. Sacred sites can take a variety of forms: a bench, a view, a feature, statute, a tree, or a region of the garden. I use the term sacred to instill a stronger feeling than the word "favorite." I encourage people to choose sites that they feel a psychological affinity with. The survey is made up of two parts, with the visitor map of the Arboretum on one side and a questionnaire on the back side. The stakeholders of the Arboretum that I distributed surveys to include: visitors, members, volunteers, board members and staff.

Stakeholders are asked to circle sites they deem "sacred" on the map. There is no limit to how many sites one can circle. If they circle more than one site they are asked to rank the order of significance of the various sites. This is a subjective and personal survey. The surveys are compiled and all sites are recorded. From compiling the data to one spreadsheet one is able to see which sites measure among the most sacred/significant to stakeholders. A range of characteristics can contribute to why a site is sacred to stakeholders.

I hope to provide basic information that people can use in the future to make more correlations. My purpose with this project is to help initiate a conversation between stakeholders and the executive board in the planning process/future master planning process. Because of the participatory role the survey requires, I hope this active involvement encourages a strong and lasting bond between the Arboretum and its stakeholders. From a horticultural view point, I hope that this information is used to protect these "sacred" sites in future master planning.

Sacred Sites of the Morris Arboretum

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INTRODUCTION

As humans, we are continually building bonds with our surrounding environments. These bonds can be encouraged through successful landscape design and/or land conservation. A combination of community development, planning, and environmental psychology can provide not only a rich understanding of how planning impacts our experience of place, but also how community-focused emotions, cognitions, and behaviors can impact community planning and development. (Finding Common Ground: The Importance of Place Attachment to Community Participation and Planning. Manzo, Perkins. P 336)

If we design with people in mind, we can salvage and foster a relationship between people and nature. Public institutions, such as the Morris Arboretum, which strive to educate the public about horticulture, should be sensitive to the needs of its stakeholders. An individual's bond to a place can be diminished if the place is destroyed or changed. Once a site is destroyed or becomes unrecognizable it is hard to return to that same place and feel all emotions and the bond you once felt.

In a majority of community development projects, residents' connection to a space is often overlooked. Although change is necessary at times for economic and community development, it should be approached with more caution. Too often the environment is destroyed in order to build a new shopping plaza. Destruction of land is a reactionary process. People have bonds to the environment. For example, their bonds may be destroyed if they were attached to a field that was just devastated for a new Wal-Mart. It is important for residents to become involved in the development process so that spaces can be preserved and therefore the residents' bonds are preserved. I feel in order to salvage and promote a relationship between people and nature, people's opinions and bonds should be taken into consideration in community redesign.

My project strives to start the conversation between stakeholders and those making executive decisions. The conversation begins with a survey, the "sacred sites survey." The survey asks stakeholders to share their sacred sites. Sacred sites have a broad ranging definition. Sacred sites can be spaces that allow people to connect with traditions, history, and/or personal memories. A sacred site can be a space where one feels a spiritual connection or where one finds relaxation. The term "sacred" was inspired by the work of the landscape architect and professor at UC Berkeley, Randolph Hester. He approaches the world of landscape architecture with the concept of designing for "ecological democracy." The part I am interested in is the democracy component. "Democracy is government by the people." (Hester, Randolph. *Design for Ecology Democracy*, p. 120.) I hope to encourage the democratic space that the Arboretum offers to its visitors. Having a democratic space from which each visitor can take away their own experience is important to its success as an institution, but also listening to visitors and giving them the opportunity to voice their opinions/concerns, is just as important.

My survey is analogous to Hester's redesign of the town of Manteo, North Carolina. Hester and a team of designers were hired to revitalize the central waterfront of Manteo. Disagreements erupted because residents felt that the contemplated changes would destroy their quality of life (p. 118). In response to the residents' concerns and disagreements, the designers

devised ways of communicating with them through interviews and surveys in the newspaper. The designers devised a list of places that residents were willing to change to accommodate tourism and places residents were unwilling to sacrifice. The designers then collected all this data and a list of significant places resulted. These significant places were spaces the residents were not willing to sacrifice. The designers termed these "Sacred Structures of Manteo." "The loss of such places would reorder or destroy something or some social process essential to the community's collective well being." (Hester, Randolph, p. 120)

Taking an interdisciplinary approach when designing is important to the success of the space. These "sacred structures" are spaces that connect residents to Manteo. By creating a survey that measures stakeholders' "sacred" sites at the Arboretum, the Arboretum can then work towards preserving, conserving, and restoring those sites that in turn connect stakeholders to the Arboretum. If we remain ignorant of stakeholders' bonds, these bonds could be destroyed, or diminished through poor future master planning. When these connections diminish so does the relationship between the public and the Arboretum. The Arboretum could suffer from loss of memberships and visitors. I hope my project builds awareness of the importance of the public participation in future master planning.

METHODS

I created a survey to measure stakeholders' sacred spaces. The survey is made up of two parts, a front and a back. One side contains the current visitor map of the Arboretum. The other side contains the survey. The survey sheet contains my intentions with the survey, the task at hand, what I mean by a "sacred" space, questions to guide their thinking, and supplemental information. The supplemental information asks: how many times one has been to the Arboretum, participants' age, and if they would like to see any changes come to the Arboretum. I distributed surveys to stakeholders of the Arboretum. Stakeholders include all users of the Arboretum; visitors, staff, board members, volunteers, and members. They are only required to have been to the Arboretum at least once in their life. The task at hand asks the participant to circle areas on the map that seem sacred to them. They were invited to write explanations and personal stories on the survey. If they did not feel their sacred site was illustrated on the map they were given, they were encouraged to make clarifying notes. They could choose as many or as few sites as they wanted. If they choose more than one site, I ask that they rank the sites in order of significance to them.

RESULTS

After the surveys were completed and collected, the data was compiled. To date there have been 77 different spaces designated as "sacred" by stakeholders. Since there was no limit on how many sites people could choose, some people chose one site while others chose five or more. As I collected the surveys, I numbered them so I could refer back to each one according to its numerical name. I have compiled the findings into three different documents. As each survey was collected I numbered them beginning with 1, then 2, and so on. I then summarized the sacred sites mentioned, in numerical order of the surveys. I have attached an example of this at the end of the paper. Another document is an Excel spreadsheet that displays the all the sites mentioned. Next to each site I recorded the number of times it was mentioned. For example, the Rose Garden was mentioned 24 times, therefore next to the "Rose Garden," I have the number 24. The sites are listed in order from least significant (mentioned once) to most "sacred" sites (mentioned on several surveys). The final document I created was a list of things people would like to see come to the Arboretum. People were not required to fill out this part of the survey, but for those who had suggestions, I recorded them. At the end of the paper is a columns graph representing the disbursement of sacred sites (as of March 16, 2011). It graphs the sites in order of significance (how many times they were mentioned).

DISCUSSION

No matter what the results were, I wanted to provide information to the Arboretum that could be useful to the various departments. I wanted to begin a conversation between stakeholders and the Arboretum, as well as leave information that could be built upon in the future.

I started this project with a few assumptions. For example, I had ideas about which spaces people would be deemed sacred. Although some of my assumptions proved to be correct, I also learned a lot about "sacred" sites in the process. I had a great time making correlations between and hypotheses from the information I received. I also discovered challenges and oversights that could not have been discovered without trial and error.

There were several challenges with the survey. The first challenge was that there were no limits on the number of sacred spaces one could choose. Therefore some people chose one site, while others chose more than seven sites. Since I did not limit anyone to the number of spaces they could choose, I had to forgo some control over the project. Measuring the bond of one person compared to another person is nearly impossible.

A second challenge was encouraging people to take their time on the survey. The time people spent on the survey varied. Some people rushed through the surveying neglecting to fill out any of the supplemental information. Other people took their time, expanding with personal stories and memories of the sites. I found that a majority of the people that took their time with the survey were staff members or volunteers, both who have a lot invested in the Arboretum.

A third challenge was difficulty in reading a map. An individual who is not familiar with the Arboretum may have a hard time orienting themselves on the map provided. This leads to participants circling one area but explaining it as another. It then is left up to me to judge which area they meant to circle. I have struggled trying to interpret their intent.

Another challenge occurred when people filled their survey out with others. I noticed people in groups of two and three tended to mark the same sites. They could very well have the same sacred sites. For instance, if a man proposed marriage to a woman in a certain area, they could both feel that site is sacred. Although there may be some overlap, this exercise is meant for people to share their personal sacred sites.

An additional challenge was that I did not limit people to choose existing site or sites that no longer exist. Some participants picked sites, specifically trees, which have been removed. Although this is a challenge to the project, it can also be beneficial information. This information can help staff think about possibly replacing these "sacred" trees.

What I found really interesting was how the sites chosen by participants generally correlated with how many times they had been to the Arboretum. Stakeholders who have been to the Arboretum a dozen or more times picked more obscure, hidden spaces. This could just be that the more time you spend in an area, the more corners you are going to discover and the more opportunities you have to explore. Participants who have been to the Arboretum less than four times picked more features. Most of the features are visible from the pedestrian path. On a visitor's first couple of times to the Arboretum, they are most likely going to follow the pedestrian path that the Arboretum has laid out for them. Therefore the features are the spaces they most likely experience during their first few visits.

I created a drawing made up of trace layers that provide a visual representation to the audience. Through the use of these trace layers one can look at the spatial relationship of the sacred sites recorded. The visuals are layers of trace that portray existing conditions and the spatial relationship between sacred spaces. There are five layers: hydrology, vehicular and pedestrian traffic circulation, vegetation (existing canopies), sacred viewpoints, and sacred spaces. The sacred viewpoints represent specific spaces in which people stand to enjoy the view from that spot, or the bench they enjoy sitting in.

These existing elements are important to the sacredness of sites. For instance, a site may be more sacred if it is near water or a site may lose sacredness if a pedestrian path runs next to it. Once these layers are placed upon each other, the spatial relationship between the elements and sacred sites is portrayed. The trace layers provide the audience with a visual image of the sacred sites of the Arboretum and their relationship to natural and installed elements.

This visual representation can be helpful for future development plans. For example, if the Arboretum is looking to build restrooms in the future, they can determine where to put them by the negative space on the map (negative space being the lack of sacred spaces). The layers can help determine where a new path should or should not be. The installation of a path could jeopardize the sacredness of a site. The trace layers help translate the information I have received

into a visual piece. The results, the trace layers, and the compiled data are just a foundation of information and findings, all of which can be built upon in the future.

CONCLUSION

I am passionate about engaging people and nature, what is it that makes the two connect, and what makes people feel they have a moral responsibility to be environmental stewards. This project allowed me to understand the spaces at the Arboretum to which people feel a connection. An overarching goal was beginning a conversation between stakeholders and the decision making process. It was Hester's approach of "Ecological Democracy" that got me thinking about how I could incorporate my interests with something that would be beneficial to the Morris Arboretum. I was interested in looking at the decision making process, how decisions are made within the Horticulture Department and how these decisions could influence one's experience at the Arboretum. To secure stakeholders' connections to the Arboretum I think it is important to hear their opinions on spaces they feel should not be altered.

"The inclusion of sacred places in the discussion changes the dimensions of decision making." (Hester, Randolph, p 125) Through my surveys, I am striving to engage the public in the decision-making process. Public institutions depend on its stakeholders' commitment and support. I hope the information that has been collected will be useful in influencing the executive board's decisions.

Making sacredness a part of the Arboretum planning process can lead to the preservation of aspects of the garden that are most important to its constituents.

This information is groundwork that can continue to be built upon in years to come. The more the Arboretum engages its supporters, the more it builds bonds with its stakeholders. The information collected can also provide supplemental information to the various departments. This survey can benefit various departments: marketing, development, and horticulture. Marketing can use the images of the most sacred sites in advertising. Through the use of familiar spaces and sites at the Arboretum, they can reach out and make that connection with their audience. The development office can use the information to promote financial support and encourage site restoration for sacred sites. Having a copy of the completed surveys can help with finding funding and support for these sacred sites. The survey is way of engaging its members and promoting stronger relationships. The horticulture department can use the trace layers to look at positive and negative space, how more sacred spaces can be created, and how they can be preserved.

"To succeed, the planners must confront very real functional and economic issues. Landscape Master Planning is as much a creative exercise in preservation and enhancement as it is an exploration of realistic development and pedagogical opportunities." (Rolland and Towers, Smith College 1994 Master Plan). As with my survey, I hope it will support functional as well as economic issues. A master plan should take into consider the social and cultural interaction between the stakeholders, the landscape, and the educational objectives of the institution.

BIBLIOGRAPHY

Hester, Randolph T. *Design for Ecological Democracy*. Cambridge, MA: MIT, 2006. Print.

Hester, Randy. "Subconscious Landscapes of the Heart." *Places* 2.3 (1985): 10-22. Print.

Hiss, Tony. "The Sacred Sites That Make a Neighborhood." Editorial. *NY Times: Real Estate Section*. New York Times, 12 Mar. 1995. Web. 9 Sept. 2010.

Janice McFarlan, among other staff members

Surveys to Visitors, Board Members-Personal Interviews

(http://ncsudesign.org/content/index.cfm/fuseaction/alum_profile/departmentID/5/startRow/3). North Carolina State Alumni Web Site.

(Future Sources) Internet Course, Historical Archives in Gates Hall, Morris Arboretum.

What people would like to see come to the Arboretum:

A pair of swans
Giant wooden insects (a return visit)
New restrooms
More summer concerts
Ongoing maintenance to the wetland trails
Tagging (assuming accession tags needs to be put on all trees)
More sculpture
Veggie garden
New sign paneling (for Oak allee, mansion site, swan pond, etc)
Delicious restaurant
BG maps, like Longwood, available online
"Do not add too much stuff"
More summer activities: with alcohol targeted toward various groups focused on different parts of the garden
Children's activities
More natives
Vegetable garden for kids
Another Patrick Dougherty sculpture
Open earlier in the morning
More planned views
Cheaper prices for seminars-$14 is way too much
A way to transport handicapped people
Better group meeting place
There should be a discussion about preservation vs. restoration vs. conservation
More sculpture exhibits
Public, pedestrian entrance at Germantown/Hillcrest
An aquatic garden with more water lilies, lotus, etc. with stepping stones across
A pier over the wetlands
Picnic areas
Trash cans
Small playground
Education Building
Douglas Fir
Native Mt. Ash
Barn owls, wood thrush
Wish we were open later in the day
Bonsai collection

Suggested improvements:

Inside the Visitor Center, show pictures of events that happened at the Arboretum in the past several weeks, such as trees, plants, and flowers in bloom, birds, and animals seen.

Need to improve access to Wetland area.

The *Out on a Limb* structure is a clever idea for a tree house; however, the silver galvanized metal fails atheistically. It should've been made with corn-ten steel (the marital that oxidizes to a rust color) for a better contextual relationship with the landscape.

Ladies restroom in the basement of Widener could use an upgrade/cleaning/repair. The same wasp nest has been there for 2 years.

TITLE: **WAKEFIELD ESTATE ARBORETUM DEVELOPMENT PLAN**

AUTHOR: **Deborah Merriam**
Historic Preservation 900 Independent Study at the University of Pennsylvania

DATE: **April 2011**

ABSTRACT:

The development of a plan to create a public arboretum from a private garden is a process that involves the incorporation of several specific plans. This paper presents a brief analysis of each planning area necessary to produce the Wakefield Estate Arboretum Development Plan. Research of the history of the Wakefield Estate, existing plans for other sites, site visits, and staff interviews at operating public institutions provided all of the necessary information to complete this analysis.

When completed, the study can be used as a model by various institutions including historic sites and private gardens and arboreta to expand their development and accessibility to the public.

Wakefield Estate Arboretum Development Plan

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INTRODUCTION

The Mary Wakefield Estate in Milton, Massachusetts is a private trust dedicated to public education. The estate is twenty-five acres that includes designed gardens, orchards, wetlands and woodlands. Historic buildings include the three hundred year old farmhouse, a Georgian mansion, large barn and a caretaker's cottage.

Mary Wakefield died in 2002 and left the estate in trust to be used for public education. It was also her wish to open the Wakefield as a public arboretum. As a graduate student in historic preservation I have accepted an internship followed by a full time position to develop and implement the strategy for converting a private garden to a public arboretum. Landscape Architecture 755, "Issues in Arboretum Management" offered the perfect opportunity to develop the framework of this plan and begin phase one, which focuses on-site research and visits to compile information that will aid in the development plan for the Arboretum.

The creation of the arboretum development plan is a two-year process. This process will unfold in several stages. Phase One includes the development of the internship, grant applications, site visits and research. Phase Two will be completed during the summer internship. This phase includes compilation of historic documentation, development of a plant records database, and the development of a landscape management plan.

Phase Three will be conducted on a part-time basis during my second year of graduate school. This phase will include the development of the interpretive plan, the financial plan, and the implementation plan. The Arboretum development plan has been unofficially approved as the topic for my master's thesis that will be presented in the spring of 2012. Upon completion of Penndesigns' Historic Preservation Program, I will begin working at the estate full time to open the Arboretum to the public.

HISTORY

The Wakefield Estate has been in Mary Wakefield's family for more than three hundred years. Mary inherited the estate from her parents Henry and Alberta Binney and married Kennard Wakefield. The Binneys and Wakefields used the property for farming including the production of sheep, hay, and apples.

Mary Wakefield was born in 1914. She grew up in the farmhouse on the estate and attended the Lowthorpe School for Women, a school focused on landscape architecture associated with the M.I.T. Architecture School. During World War II Mary returned home to run the family farm. She continued to foster her love for gardening through design and horticulture. She designed and implemented several formal areas on the estate in a style loosely based on the work of landscape designer Beatrix Farrand. Mary worked closely with propagators from Harvard's Arnold Arboretum to develop a diverse plant collection. She worked extensively on the landscape rehabilitation plans for the Boston Common and was active in supporting Massachusetts legislation for the protection of ecological areas. Mary Wakefield was an avid

plant propagator and patented several dogwood cultivars. Mary died in 2002 and left the Wakefield in trust to be used for public education.

Living Collections

The Wakefield Estate has a diverse collection of woody plants. Many woody plants in the collection are from the Arnold Arboretum including dove trees, parrotias, giant sequoias, lacebark pines, and paperbark maples. The most significant plant collection at the Wakefield is the dogwoods. There are over three hundred dogwoods on the property. The Wakefield Estate holds the patents for six of theses varieties. These dogwoods make up a significant part of the designed gardens at the Wakefield that include several alles that are part of a spectacular spring display.

Educational Programming

The mission of the Wakefield Estate is: "To promote lifelong participatory learning using the land and resources of the estate through collaborative partnerships with schools and community organizations."

The current success of the estate has been in educational programming and community outreach. The Wakefield partners with several of the schools in Mattapan, Boston, and Milton to educate 4^{th}, 5^{th}, and 6^{th} graders on the property as part of their public school science curriculum. The students visit twice a year to view lifecycles of plants and animals in their natural environment.

Other educational programming includes an archeology summer program operated by Boston University Ph.D. students, a high school horticultural internship program, and archival and curatorial fellowships for graduate students from Simmons College.

In the summer of 2010 the Wakefield partnered with the Mattapan schools to design and construct interactive gardens at the school sites. Local nurseries donated the plant material, soil, and equipment and planning and garden implementation was done by the students and faculty. Horticulture interns from the estate take care of these gardens during the summer. This program will continue to expand to include several more urban K-6 schools.

Arboretum Development Plan

The Wakefield Arboretum will continue to uphold the mission serving the community as an interactive outdoor learning center to promote the interaction with those resources as a learning tool. The planning process will always reflect this vision moving forward. The development of the Arboretum plan is a two-year process. Three phases of the project have been identified. Various groups will work several parts of the plan on simultaneously. Changes and updates to the plan will occur on a continual basis.

PHASE ONE: Internship and Grant Proposals

This project began with the internship proposal submitted to the director and trustees of the organization of the Wakefield. Originally the proposal consisted of the development of a landscape management plan. Currently, the estate has no clear management strategy for the landscape. The plant collection is an extremely important feature of the property; the lack of a comprehensive management plan has led to the neglect of this component of the estate. Invasives including buckthorn, Norway maple, muliti flora rose, ground ivy, and garlic mustard cause major damage to many areas of the property. The lack of selective tree removal has led to the disastrous scenario of an overcrowded collection. A landscape management plan must be created and implemented as a priority to the further success of the property as a learning facility focused on the natural resources it offers.

The director and trustees accepted a landscape management plan internship proposal. The project expanded to include an Arboretum development plan as a master's thesis topic and the permanent position of Landscape Manager and Director of Arboretum Development.

An integral part of the planning process is research. Site visits conducted as part of the Morris Arboretum Management class initiated a research project that includes visiting twenty-five gardens and arboreta throughout the United States. The grant proposals, methodology for interviews, and interviews are the focus of this semester's independent study.

Site Visit Methodology

1. Submit grant proposals for traveling fellowships through Penndesign. [16]
2. Develop list of criteria for garden selection.
3. Compose list of sites[17]
4. Develop methodology for interviews. [18]
5. Visit sites
6. Compile data

[16] See Appendix A Grant Proposal

[17] Ibid

[18] See Appendix B Sample Interview

PHASE TWO: Summer Internship

Historical Documentation

The Arboretum master plan will include a detailed history of the Wakefield Estate. Graduate Students from Boston University's Historic Preservation Program are currently compiling the National Register nomination for the Wakefield Estate. The nomination includes a landscape history documenting land use from Native American occupation to current property use.

A historic landscape inventory is being compiled with the help of the education director and the executive director of the Wakefield Estate.

Boston University Ph.D. students are developing the site's archeology map that will be a key piece of information in the development of the Arboretum master plan.

Plant Documentation

The documentation of the Wakefield Estate plant collection will be at the center of the Arboretum management plan. The Wakefield archives holds thousands of pieces of information on various plants, their origin and location on the Wakefield property. All documents are currently being catalogued to be used as references for identification and history. In 2005 tree care specialists conducted a conditions survey of the unique and important woody plants at the Wakefield. This inventory provides detailed conditions information that will be very helpful in prioritizing trees in the collection for tagging and identification. Plant documentation will provide the bulk of the work for the summer of 2011.

Plant Records Methodology

With the help of Grace Chapman at Temple Ambler Arboretum and John Hinchman, Professor at the University of Pennsylvania specializing in digital media, I developed a database that will be used to record and begin tagging the plant material at the Wakefield Estate.

Originally, BG Base was considered the desired method of plant recording, but after interviewing staff from other arboreta it became clear that BG Base is not currently economically or logistically feasible. The access database can be loaded and used with GIS software to provide a detailed mapping system that can be linked with the archeology and infrastructure maps for the estate.

Recording

Using the zone map that was created for the landscape management plan zones will be prioritized for phase l of the tagging process.[19] At this stage unless there is clear documentation about the specific plant we will just be assigning numbers to the plants and including basic documentation: size, common name and a brief conditions survey. Eventually the following information will exist for each plant. This recording process is ongoing.

- A unique accession number
- Identification (scientific name and common name)
- Authority (person who published the scientific name)
- Provenance or source information about when and from where the plants entered the collection.
- Location of the plants within the collection by zone, garden and x/y coordinates
- Growth habit (tree, shrub. perennial, vine, groundcover, bulb, succulent, annual)
- Health
- Size (height, trunk diameter at breast height, width of canopy)
- Conservation status (rare, endangered, threatened)
- Use of plant for food or medicine
- Causes of plant removal/death
- Ornamental characteristics

In January 2011 a project grant was submitted for hiring two summer interns to begin tagging the collections for five weeks. The project grant was accepted interns are currently being interviewed.

Landscape Management Plan

The Wakefield Estate has one full time horticulturalist, part-time summer help, and five horticultural summer interns. Tree work is contracted out to tree specialists. Currently there is no landscape management plan for the Wakefield Estate. A coherent management strategy is needed to provide the basic level of maintenance specifically invasive control and collections care. The landscape management plan is being developed using the Arnold Arboretum landscape management plan as the template. [20]

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[19] See Appendix C

[20] Arnold Arboretum Landscape Management Plan http://arboretum.harvard.edu/about/planning/landscape-management-plan/Accessed January2, 2011

Methodology

Using the site-engineering map produced in 2006 for the Wakefield Estate, we developed a base map of the property.

In December 2010 we established zones that will be used in all mapping projects of the estate. The proposed zones for the estate are based on a list of criteria the included:

- Historic evolution of the property
- Original land surveys
- Formal and designed gardens
- Working landscapes
- Historic names of character areas
- The property is divided into six zones that include: North Lot, Former Pasture Section of North Lot, South Lot, Farmhouse Lot, West Zone, and New Lot.

Proposed Plan

The plan organizes the landscape into six management zones that provide a structure for staff assignments and identify specific care needs and projects for collections and landscape areas. Zones encompass areas that are contiguous and share similar challenges, collections themes or management requirements. Zones are treated as a unit with common specifications for daily, monthly and annual care. Specifications are written to attain targeted standards of care and presentation. The following information is provided to guide the care and management of each zone:

1. Management Priority: Zones are designated as"high","moderate" or "low" priority based upon their relative importance within a given year, as determined by the landscape director of landscape management. Priorities may vary annually, depending on special projects, particular landscape issues (e.g., pest outbreaks, winter damage, etc.) and larger organizational needs.
2. Management Intensity: The amount of resources (staff time, equipment and materials, team support, etc.) needed to maintain a given zone at the desired standard is designated as: high, medium and low.
3. Area Profile: A general profile of each area describes distinguishing characteristics, unique resources, history and special challenges.
4. Special Priorities: Tasks and projects of high priority that require ongoing attention and commitment.
5. Annual Care Plan: All tasks needed to maintain an area is listed by season, in descending order of priority.
6. Noxious Weeds: Extant weed species requiring management.
7. Pests and Diseases: Pests and diseases that are currently a problem or may be in the future.
8. Long-Term Projects/Tasks: Projects and tasks to be accomplished by Arboretum staff, within the annual operating budget, are listed for each zone within a 2-5 year time frame. These

include landscape improvements, plant acquisition, vegetation management, restoration projects, and pest and disease abatement.

9. Capital Projects: These larger projects require capital investment outside the operating budget. They include hardscape design and construction, irrigation and other projects to be completed within 3-5 years.
    - Implement landscape management plan
    - Develop record keeping system

Horticulturalists will be expected to document their work. Work lists will be printed and distributed monthly.

PHASE THREE:
Interpretive Plan, Financial Plan, Implementation Plan

Interpretive plan

The interpretation plan will strongly reflect the Wakefield s mission of education and community engagement. The following definition of interpretation provides the framework for developing a comprehensive interpretive plan:

> "Interpretation is conversation, guided interaction, or any communication that enriches the visitor experience, by making meaningful connections between the messages and collections of our institution and the intellectual and emotional world of the visitor."[21]

Plan Methodology

1. Background and project context
2. Vision, Outcomes, and Recommendations
3. Stakeholders in the Wakefield Estate including, staff members, board members, community members, education professionals, and planning professionals will be interviewed to establish the important elements of an interpretive plan. Methods for engaging these stakeholders will include one on one sessions, and facilitated group meetings.
4. Youth interpretation will be a major component of our plan. School children from the ages of 9 to 17 will be given the opportunity to decide what they think is important about

[21] 170Cunningham, Mary Kay. The Interpreters Training Manual for Museums. Washington, DC: American Association of Museums, 2004

the Wakefield Estate. This interpretation model is based on the "Journey to Hallowed ground educational model."[22] The 'Of the Student, by the Student for the Student Program' is a nationally recognized and award winning service learning program that combines movie making with on site natural history and authentic experiences to connect young people with the landscape and its history. Children between the ages of 9 and 17 will be given recording tools to document the Wakefield estate and give presentations about their own interpretation of the property.

5. Visitor analysis: It will be necessary to understand needs of the visitors that will be coming to the arboretum for a variety of programming and to experience the landscape.
6. Media and methods: The development of interpretive maps, brochures and a wayfinding system will be a major contribution to the interpretive plan.
7. Levels of interpretation: The interpretation of the estate will consist of three levels.
8. We have highlighted important aspects of the landscape based on the age level of the visitor. Our primary goal for the wayfinding system will be t develop the system as part as the educational programming for the 4th 5th and 6th grade visitors.
9. Implementation priorities and timeline

Financial Plan

The Wakefield Estate Trust has a financial plan and yearly operating budget. The arboretum development plan will include a financial plan that will exist within the parameters of the estate financial plan.

Methodology

1. Research financial plans for arboreta of similar size
2. Prioritize projects for funding
3. Maintenance
4. Funding strategy

Funding Strategy

1. Statement of why you need to raise funds for the garden
2. Strategic goals for the Arboretum
3. Financial goals for the Arboretum
4. Policies, if any, related to these goals
5. Strategies to cultivate major donors, foundations, and corporations
6. Strategies to solicit specific market segments
7. Time frames for achieving the goals
8. People responsible for achieving the goals

[22] http://www.hallowedground.org/content/view/536/52/ *Accessed March 2, 2011*

Implementation Plan

The implementation plan will be developed during the final six months of the project. This plan will rely heavily on the financial plan and infrastructure development plan. Project implementation will be done in a phase format. The phases of implementation will include:

1. Building infrastructure
2. Hiring personnel
3. Continued plant records tagging
4. Recruitment of volunteers
5. Continued removal and replacement of specimens

CONCLUSION

The Mary Wakefield Arboretum Development Plan will take more than two years to complete. Phase development of the plan will be a useful tool for an organized transformation from private to public. Changes to the plan will be continuous in an effort to make sure all of the elements in developing a successful plan are met.

APPENDIX A: Funding Proposal

Susan Cromwell Coslett Traveling Fellowship
School of Design, University of Pennsylvania

I am seeking the Susan Cromwell Coslett Fellowship to fund site visits to twenty-five gardens and arboreta in the United States and British Columbia. These site visits are critical to understanding how smaller gardens and arboreta operate, including their funding strategies the condition their collections, and educational programs.

The results of this research will provide important information that will be used as the basis for my master's summer internship.

The Mary Wakefield Estate in Milton, Massachusetts is a private trust dedicated to public education. The estate consists of twenty-five acres of designed gardens, orchards, wetlands and woodlands and a Georgian mansion.

As an intern at the Wakefield Estate, I will conduct a feasibility study for the conversion of a private estate into a public garden and arboretum with a strong educational mission.

The budget for my internship does not include funds for such visits. There is no room in my school loan budget for travel. This grant will allow me to observe collections and speak with staff and would greatly help me in developing an appropriate strategy for opening a private landscape for public use and education.

The goal of my internship is to write a proposal to open the Wakefield as a public garden and arboretum. My intention is to develop an innovative strategy by creating an interactive landscape, promoting strong public involvement for education and community building, engaging local students at all levels from visitor services to horticulture to education. The opportunity to do hands on learning provides important job training for students of all levels. The conversion plan will include a financial management plan, a landscape management plan, a volunteer program and an expanded education program. The final result will be the proposal for my master's thesis.

The director of the Wakefield is focused on community engagement and has the freedom and flexibility to develop some inventive strategies. The Wakefield has already hosted such diverse programs as the International Society of Arboriculture's women's tree climbing clinic for arborists from all over the country and a week-long seminar held by the Harvard Landscape Institute to discuss how the property should be used and interpreted.

The Wakefield is partnered with several of the schools in Mattapan, Boston, and Milton to bring elementary school students to the estate as part of their public school science curriculum. The students visit twice a year to view lifecycles of plants and animals in their natural environment. The enthusiasm professed by students and teachers in this program make it clear that programs like these are successful at providing a high level of educational value.

Previous to entering graduate school, I was employed by the Wakefield to renovate and document the plant collection and formal gardens. The plant collections suffered a twenty-year period of neglect. Many of the gardens were filled with invasives and the collection of over three hundred dogwoods was in serious need of repair and care. I had the opportunity to expose a designed landscape that evolved for more than fifty years. During this renovation many questions were raised as to the treatment of a historic landscape that has suffered a long period of neglect. Understanding the importance of preserving an historic landscape while allowing it to evolve became the reason I decided to pursue a master's degree in preservation. I have spent several years doing the hands on horticultural work and learning about landscapes and their care. By pursuing my Masters degree at Penn, I am provided with the necessary tools to effectively plan and manage historic landscape collections for future generations.

If historic landscapes are to be protected, we must make them relevant to the needs of today's communities, having the opportunity to visit a variety of gardens and arboreta will provide a greater understanding of the adaptability of these properties to changes in the field of landscape preservation and management for the twenty–first century.

Project Goal

Develop plan to convert a private estate into a public garden and arboretum.
Plan will be the basis of master's thesis proposal: Planning and managing historic landscapes in the twenty-first- century.

Goals at each site.

1. View the gardens and arboreta. Design, history, condition, collection.
2. Interview financial planning personnel.
3. Interview horticulturalists and arborists about the management and care of the collections.
4. Study public programming and fundraising strategies.
6. Review preservation strategies for historic landscapes.

The fellowship will allow me to research gardens and arboreta of similar size and scope to the Wakefield. The list of criteria is based on factors relevant to the conversion of the Wakefield from a private to a public landscape.
Criteria

1. Grow historic plant collections.
2. Converted private gardens to public gardens.
3. Use propagation facilities.
4. Offer education programs that are free or subsidized.
5. Offer internships to high school aged students.
6. Use test gardens to help fund their programs.
7. Seek unique fundraising strategies.

8. Have a strong volunteer program.
9. Have historic houses on the property.
10. Partner with other local organizations to increase visitation and exposure.
11. Are similar climate zones to the Wakefield.
12. Focus on one particular plant family or species.

List of Sites

Maine Botanical Gardens, Maine
Viles Arboretum, Augusta, Maine
Abbey Aldrich Rockefeller garden, Mount Desert, Maine
Polly Hill Arboretum, Martha's Vineyard, Massachusetts
New England Wildflower Society, Sudbury, Massachusetts
Tower Hill Botanic Garden, Worcester, Massachusetts.
The Botanic Garden of Smith College, Northampton, Massachusetts
University of Massachusetts Test Gardens, Amherst, Massachusetts
Heritage Museum and Gardens, Sandwich, Massachusetts
Wave Hill, New York
Cornell Plantations, Ithaca, New York
Planting Fields Foundation, Oyster Bay, New York
Leonard S. Buck Garden, Morristown, New Jersey
Temple University Arboretum and Test Garden, Ambler, Pennsylvania
Bartram's Garden, Philadelphia, Pennsylvania
Berry Botanic Garden, Portland Oregon
Elk Rock Garden, Bishops Close, Portland, Oregon
James F. Bybee and Howell Territorial Park Sauvie Island, Oregon
Deepwood Estate, Salem, Oregon
Shore Acres State Park, Coos Bay, Oregon
Mount Pisgah Arboretum, Eugene, Oregon
Botanic garden and Center for Plant Research, University of British Columbia, Vancouver, British Columbia
Butchart Gardens, Vancouver, British Columbia
Vancouver Compost Demonstration Garden, Vancouver, British Columbia
Van Dusen Botanical Garden, Vancouver, British Columbia

Budget

Gardens and arboreta will be visited over a period of two to three days each during weekends over the summer. Ten days will be necessary for west coast travel.

Maine
Car Rental $170. Fuel $85 Miles 600
3 nights Hotel $375
Food $100

Massachusetts
Car Rental $170 Fuel $55 Miles 375
3 nights Hotel $375
Ferry $120
Food $125
New York, New Jersey and Pennsylvania
Car Rental $170 Fuel $85 Miles 600
3 nights hotel $375
Food $125
Oregon and Vancouver
Airfare $800
Car rental $400 Fuel $100 Miles 700
Hotel for nine nights $1,125
Food $300
Entrance fees $120
Funding total $5,180

APPENDIX B: Bartram's Garden Questionnaire

Bartram's Garden Questionnaire

(Date, Staff member)

How many employees does the garden have?

What is the mission of the garden?

How do you convey the historic aspects of the property?

What are major obstacles to operating this garden?

Do you have a landscape management plan?

What are you doing to increase visitation?

What could be done to improve facilities structure?

How do you engage the community?

Can you talk about the educational programming?

Do you have a volunteer staff?

Do you offer discounts for schools that don't have a big budget?

How do you keep plant records?

How do you stay relevant?

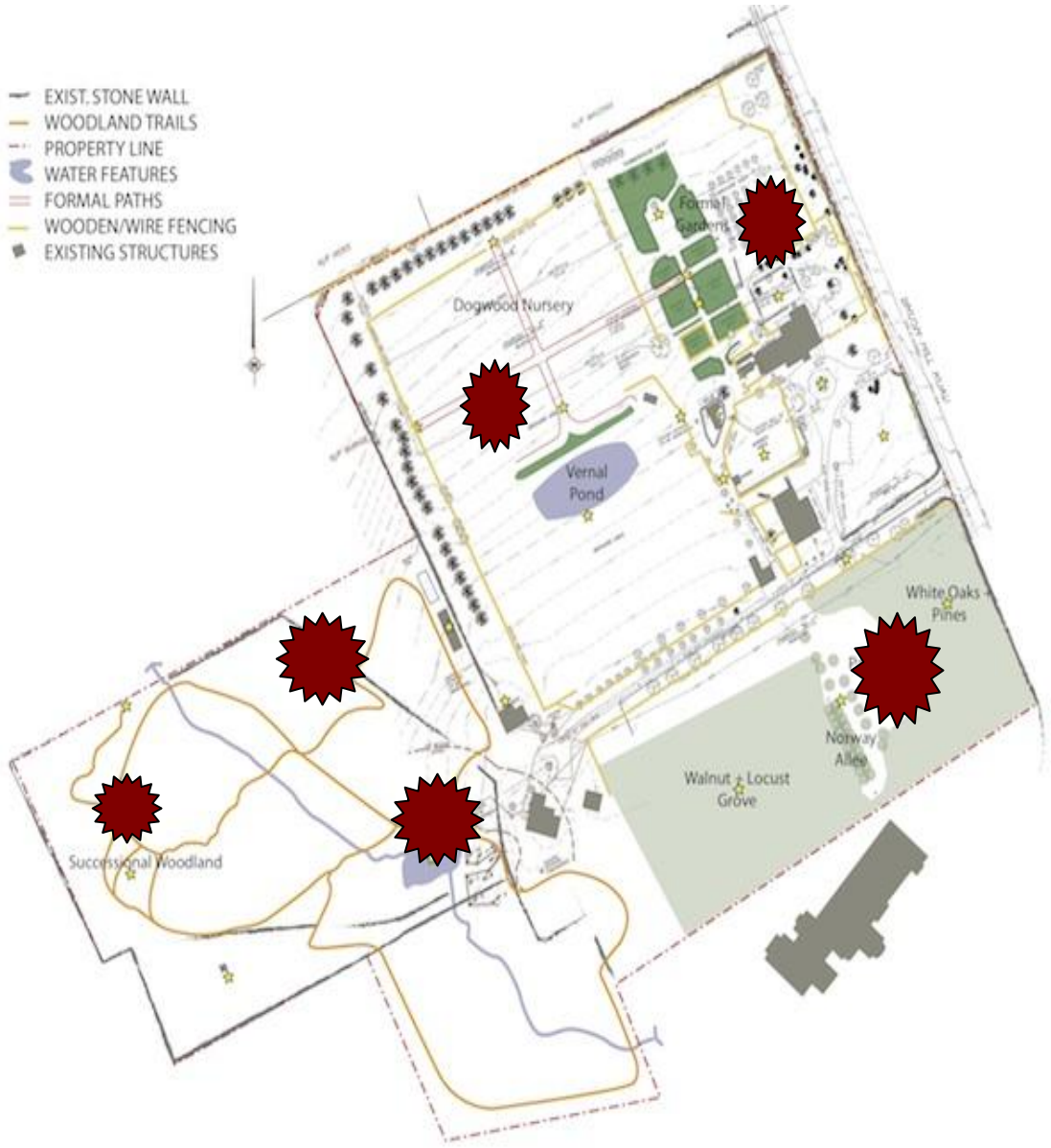
Do you partner with other organizations?

Can you talk about some of your fundraising strategies?

Take you talk about maintenance issues?

What is your role here?

APPENDIX C: Wakefield Estate



REFERENCES

Gagliardi, James A. 2010. "An Analysis of the Initial Planning Process of New Public Horticulture Institutions." Longwood Gardens. University of Delaware Thesis.

Olin Partnership, Landscapers. March 2003. "The Woodlands, Landscape Preservation and Enhancement Strategy."

Rakow, Donald and Lee, Sharon. 2011. Public Garden Management, John Wiley and Sons, NJ.

Schulhuf, Richard. 2nd Edition, 2008. Arnold Arboretum Landscape Management Plan Update. Arnold Arboretum, Boston, MA.

Viridian Landscape Studio. 2008. Susan Maxman and Partners, Cahill Associates, Bruce Brooks and Associates. Bartram's Garden Landscape Master Plan .

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