2009

Managing Infestation of the Invasive Viburnum Leaf Beetle (Pyrrhalta viburni) at the New York Botanical Garden

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November 30, 2009

The New York Botanical Garden

About The Garden

The New York Botanical Garden (NYBG; the Garden), located in Bronx, NY, is the largest of its kind in the United States and is a National Historic Landmark. It is, in its entirety, a museum of plants, an educational institution, and a scientific research organization. Its grounds covers 250 acres of the Bronx and includes 50 curated display gardens and a 50-acre old growth native forest. The Garden's 250-acre landscape also includes hills, rock outcrops, the Bronx River and a number of smaller streams, waterfalls, and ponds ("About the Garden," 2009).

The Garden's curated living collections include over one million different plants and its herbarium, the fourth largest in the world and largest in the Western hemisphere, contains 7.3 million preserved plant specimens. It is estimated that most of the world's plant species are represented in the NYBG herbarium (estimates on how many plant species exist in the world range from 200,000 to 400,000) (D. Atha, NYBG Research Botanist, personal communication, October 20, 2009).

In addition to the NYBG landscape and plant collections, The New York Botanical Garden also has the most important botanical and horticultural library in the world. The Garden's *Enid A. Haupt Conservatory*, a New York City Landmark, is the largest Victorian glass green house in America and the other NYBG greenhouses are the most sophisticated facilities of any botanical garden in the United States ("About the Garden," 2009).

Garden History

The New York Botanical Garden was founded in 1891. In the early 19th century Nathaniel Lord Britton, a botanist from Columbia University, and his wife (another botanist) visited England's Royal Botanic Gardens and were so inspired by it that they, along with the Torrey Botanical Club, decided that New York also needed a magnificent botanical garden. The location that was selected is the current location in the Bronx borough of New York City. The land was previously part of a large estate owned by Pierre Lorillard, a wealthy tobacco merchant of the time ("Mission and History," 2009).

On April 18, 1891 the New York State Legislature put the land aside so that "a public botanic garden of the highest class" could be created for New York City and its many out of town visitors. Benefactors including Andrew Carnegie, Cornelius Vanderbilt, and J. Pierpont Morgan, in a public-private partnership that is still alive today, funded the grounds and buildings. Nathaniel Lord Britton, attributed with conceiving the idea for the Garden, was appointed as the first director of the NYBG in 1896 ("Mission and History," 2009).

In 1902 the Garden's most picturesque and famous building, the *Enid A. Haupt Conservatory* opened. It was declared a New York City Landmark in 1973 and restored in 1997. It now contains the "World of Plants", a tour of many of the different habitats in which plants thrive all over the world, including tropical rain forests, deserts, carnivorous plants, aquatic plants, and "the world's most comprehensive collection of palm trees under glass". Other historic buildings on the grounds include the *Stone Mill* (previously called *Snuff Mill* as per its past purpose), built in 1840 and now another New York City Landmark, the *Library,* built in 1901, and the *Stone Cottage*, built in 1840 ("Mission and History," 2009).

Mission and Function of the Garden

The New York Botanical Garden mission statement declares that NYBG "is an advocate for the plant kingdom," ("Mission and History," 2009). The Garden peruses this mission through its role as a museum of living plants, its education programs in horticulture and plant science, and its research programs in the International Plant Science Center. The New York Botanical Garden also strives to "teach the public about the values and workings of the natural world; explore the benefits that plants provide to humans around the globe; help conserve land resources; and, use science to study and better understand the plant kingdom, plant diversity, and the need to protect it," ("Mission and History," 2009).

Ongoing Projects at the Garden

The work of the New York Botanical Garden is most noticeable to the visiting public through its magnificent horticultural displays, special shows and meticulously maintained grounds. The NYBG also works behind the scenes to ensure that they fulfill their mission for the advancement of science, education, and conservation around the world. There is an enormous network of scientists working in the Garden and around the world collecting plants for medicinal research and herbarium cataloging, studying specific plant species and their environmental roles, and much more. The on-site Pfizer laboratory only serves to expand the global reach of NYBG's scientific projects even further.

NYBG also offers an exceptional education program for children and adults alike. They offer classes ranging from garden photography to home gardening and from botany to professional horticulture.

Scientific Research

Scientists of the NYBG have conducted research and undertaken conservation projects all over the world for over 100 years. The Garden's International Plant Science Center "is a world leader in plant research and exploration, using cutting-edge tools to discover, document, interpret, and preserve Earth's vast botanical biodiversity." The Center's scientists describe and name upwards of 50 new plant species every year "in a race to catalog the world's plant diversity before it is lost to deforestation and degradation of natural habitats," ("Scientific Research: Plant Science Center," 2009). Scientists in the Center cover a wide range of fields including plant systematics, economic botany, ecology, molecular systematics, and plant genomics. In May 2006 the Center was awarded a valuable gift with the opening of the Pfizer Plant Research Laboratory ("Scientific Research: Plant Science Center," 2009).

The scientific reports of NYBG scientists are posted in The New York Botanical Garden Press, one of the largest science publication programs of any botanical garden. Some research topics include bat/plant interactions in the neotropics, DNA bar-coding of the New York Botanical Garden forest, macro fungi of Costa Rica, and many more ("International Plant Science Center: Field Research," 2009).

Education

NYBG offers a graduate study program that was established in 1896. The program includes CUNY, Columbia, Cornell, Fordham, NYU, and Yale Universities ("Scientific Research: Plant Science Center," 2009). Aside from the graduate program, NYBG has a large public education division for both children and adults alike. The Everett Children's Adventure Garden and Ruth Rea Howell Family Garden both offer a large variety of indoor and outdoor learning opportunities in plant science. For schoolteachers, the Garden offers a professional development program allowing teachers to expand upon their knowledge of plant science and ecology. The NYBG also has a curriculum development program that works with academic publishers to develop textbooks and learning kits. Finally, the NYBG's Continuing Education Program offers over 500 classes for adults and the School of Professional Horticulture provides two-year courses for students who wish to enter into full time horticultural work ("Education: Public Education for Children and Adults," 2009).

Significance of the Garden's Work

The work of the NYBG, though not always widely reported to the public, is nonetheless significant on many levels. Today, an important goal of any institution is to implement policies and practices to reduce its environmental impact footprint (e.g., carbon footprint, water conservation, etc.) and many have instituted "green" programs. The Garden is no exception and it has launched a major greening and sustainability project, which, though still in its early stages, has already drawn outside public attention and had success.

In balancing its mission to the public and the global environment, the NYBG also considers the environmental health and sustainability of the natural and cultivated landscape within its grounds. The Garden has multiple large-scale projects in motion such as maintaining and restoring curated collections, restoring old growth native forest habitat, and preservation of riparian habitat along Bronx River. All of these projects are executed in the most environmentally conscious manner possible to better preserve the natural landscape of the Garden as well as the global environment.

Dealing with Environmental Challenges

In this "greening age", the New York Botanical Garden has begun to expand its commitment to preserving its environment as well as the planet's. The Garden now has a "Sustainability and Climate Change Program" which is focused on identifying and reducing carbon emissions, revising certain maintenance and horticultural practices, controlling and removing invasive species, engaging volunteers to collect climate change data, switching from oil to natural gas in buildings and tour trams, adding more efficient lighting fixtures, motors and other building equipment, and continuing to educate the public on climate issues ("Sustainability and Climate Change Program: What the Garden is Doing," 2009).

The NYBG is extraordinarily dedicated to maintaining not only their cultivated ornamental plantings, but also the natural landscape of the area. The Garden is home to over 50 acres of old growth forest. This area is one of the last remaining pieces of land in the Bronx area that has been relatively untouched by the mass urbanization of the area and remains much as it was at the turn of the 19th century (except for natural changes that take place over time). Unfortunately, with the surrounding urbanization and the natural changes time brings, the old-growth forest is slowly being overtaken by non-native plant and animal species, which are degrading the habitat.

The NYBG has launched a large-scale project to restore the forest ecosystem. The research and findings presented in this paper regarding infestation by the Viburnum Leaf Beetle (*Pyrrhalta viburni*) are as a result this restoration initiative. The restoration project involves the removal of invasive plant and animal species and the re-establishment of native species. The project also includes restoration of all the trails and signage in order to make the forest (one of the less visited areas of the Garden) more appealing and educational for the public.

Undesirable species targeted for removal include: Amur Corktree, Amur Honeysuckle, Linden Viburnum (*Viburnum dilatatum*), Japanese Honeysuckle, Porcelinberry, Devil's Walking Stick, Japanese Knotweed, and Oriental Bittersweet.

Native species being planted include: White, Swamp White, Red, Black, and Pin Oaks, White and Green Ash, Tulip tree, Sweetgum, Hophornbeam, Musclewood, Witch-hazel, Maple Leaf Viburnum (*Viburnum acerifolium*), Arrowood Viburnum (*Viburnum dentatum*), Red and Sugar Maple, Shadbush, Flowering and Alternate Leaf Dogwood, and Spicebush.

To date, upwards of 500 non-native trees have been removed and approximately 4,000 to 5,000 new trees and shrubs planted (Figure 1) (J. Arcate, personal communication, October 20, 2009). The Bronx River, which meanders through the forest, adds a critical riparian corridor for wildlife complete with open water, wetlands, and deciduous shrub and tree floodplain habitat. The Bronx River is the only fully fresh water river in New York City, and due to its extremely close proximity to highways and urban neighborhoods, has fought a long battle with pollution. Various local community and New York City organizations have launched projects to clean up the river with varying success. The New York Botanical Garden is playing a major role in this effort. Recently, the NYBG received a $350,000 grant from New York State's Attorney General (Andrew Cuomo) for funding of a "green infrastructure" project that will attempt to reduce and treat storm water discharge into River. The plan is to install more permeable pavement, tree wells to capture storm water, and discharge piping with cascading pools. This project will also tie in with the forest restoration, as it also plans to stabilize the River's shoreline and restore it by adding native trees, shrubs, and groundcover plants ("Garden Receives Funding for Bronx River Protection," 2009). All of these measures will incrementally help to reduce the Garden's impact on the river while promoting improved sustainability practices.

Future Steps

Once planning is complete, the projects need to be put into action while minimizing major compromises or changes that would lessen their effect. Once initiated, the projects need to be funded, staffed and maintained until key goals and objectives are achieved. For example, once the forest has been restored, it will be necessary to monitor progress and continue to remove invasive species as they appear. Regarding the Bronx River, once the "green infrastructure" has been installed, elements of it (e.g., pipes, catch basins) will need to be maintained, updated, and possibly expanded.

Potential Garden Program Enhancements

The NYBG has always been an institution driven by science, education, and the conservation of natural landscapes and their associated biological communities. In its management of the grounds throughout the Garden, for multiple users and purposes, its staff does an excellent job of maintaining and preserving the environment through application of sustainable and "green" practices. These practices include the responsible application of various pesticides and herbicides, use of natural fertilizers, responsible watering practices, energy efficient mechanical and lighting systems in buildings, and low or zero emissions trams for the visiting public.

One enhancement that the Garden could make is to expand their green infrastructure plans to the rest of the facilities on the grounds. Alternative energy sources such as solar and/or wind energy could be integrated into existing infrastructure where possible as well as installing more energy saving utilities in buildings. Water saving/recycling features could also be added to some facilities to reduce water use.

Controlling Infestation of *Pyrrhalta viburni* at The New York Botanical Garden

Introduction to Infestation, Pyrrhalta viburni, and Viburnums

Pyrrhalta viburni (Viburnum Leaf Beetle or VLB) is an invasive beetle from Europe that feeds voraciously and exclusively on flowering shrubs of the genus *Viburnum*. Since the appearance of the VLB in North America around 1947, they have spread remarkably throughout the Northeast including the majority of New York State where it was first recorded in 1996. This paper not only documents VLB infestation at the NYBG, it records for the first time, the occurrence of this invasive beetle in Bronx County. Equipped with this information, the NYBG is now working quickly to control the infestation before it reaches an intolerable level.

About the Infestation

Pyrrhalta viburni was identified in New York in 1996 around Lake Ontario. The VLB is native to Europe and is found throughout most of the continent. Since *P. viburni* was introduced, it has spread rapidly throughout Northeast USA into New York, Maine, Pennsylvania, Vermont, parts of Ohio, and most likely Connecticut, New Jersey, and Massachusetts as well. It has also spread north into Canada in Ontario, Canadian Maritime Provinces, and British Columbia. ("Viburnum Leaf Beetle Citizen Science [VLBCS]: The Pest," 2009) (Figure 13).

About *Pyrrhalta viburni* (Viburnum Leaf Beetle)

Pyrrhalta viburni only infests and feeds upon several species of deciduous shrubs and trees of the genus *Viburnum*. The VLB goes through only one life cycle per year, but in that time they inflict significant damage. In areas that become heavily infested, the VLB can extirpate entire stands of *Viburnum* in just a few growing seasons. The females lay upwards of 500 eggs on twigs and new growth stems in late June through mid July and sometimes as late as October (Figure 2). The female chews small holes in the plant in which she lays about 8 eggs, then seals the hole with a cap made from chewed bark and excrement. These caps also function as a sponge to trap water and keep the humidity favorable for the eggs.

These eggs rest over the winter and then hatch in late April through early May. The larvae that hatch are incredibly destructive, feeding on the new foliage until the early part of the summer (Figure 3). The larvae go through three instars (development stages) and shed their skin in between each one. Several larvae are usually found feeding per individual leaf. The larvae begin feeding on the underside of the leaves, eating between the veins. The process is referred to as "skeletonizing" the leaf (Figure 3) and is one of the more obvious, telltale signs of a VLB infestation. Several larvae per leaf can lead to the defoliation of an entire shrub in about one larval cycle.

When the larvae are ready to pupate in early to mid June, they crawl down the stem and trunk and penetrate the soil where they pupate for three to five weeks. Pupae require moist soil to develop into adults. Soil conditions that are too wet or too dry decrease their survival rate. When the adults emerge in early July, they ascend the plant and feed on more of the foliage, mate, and lay eggs until the first killing frost (Figure 4). This is also the stage when adults migrate to new plants, spreading the infestation. The entire VLB life cycle takes from 8-10 weeks ("VLBCS: The Pest," 2009).

The voracious nature of all the *Pyrrhalta viburni* life stages, its rapid reproductive rate, a lack of sufficient numbers of natural predators, and the beetle's ability to easily migrate as adults are all factors that combine to make the VLB a rapidly spreading invasive pest species and a significant threat to our native Viburnums.

About Viburnums

There are from 150 to 175 species of woody shrubs in the genus *Viburnum; P. viburni* does not feed equally on all of them. Certain *Viburnum* species are more susceptible to infestation than others. Species classified as "highly susceptible" are usually the first to be infested and, in an uncontrolled repeated infestation, can be destroyed in 2-3 years. The VLB mostly prefers the *Viburnum dentatum* complex (Arrowood Viburnum) (Figure 5) to the other *Viburnum* species. However *Viburnum trilobum/opulus* (American/European Cranberry Bush Viburnum) (Figure 6), *Viburnum* *nudum* (Smooth Witherod Viburnum), and *Viburnum rafinesquianum* (Rafinesque Viburnum) are also highly vulnerable species ("VLBCS: Susceptibility to Infestation," 2006). All of these species, with the exception of *Viburnum rafinesquianum*, can be found at the NYBG.

Viburnum species categorized as "susceptible" are those that may eventually be destroyed, but only after the highly susceptible *Viburnum* species have all been destroyed. Susceptible species include *Viburnum acerifolium* (Maple Leaf Viburnum) (Figure 7), *Viburnum lantana* (Wayfaringtree Viburnum), *Viburnum rufidulum* (Rusty Blackhaw), *Viburnum sargentii* (Sargent Viburnum), and *Viburnum wrightii* (Wright Viburnum) ("VLBCS: Susceptibility to Infestation," 2006). *Viburnum wrightii and Viburnum acerifolium* are both found at the NYBG.

Viburnum species categorized as "moderately susceptible" are those that exhibit different degrees of susceptibility depending on characteristics of the *Viburnum* species and are not usually destroyed by the VLB. Some of the more notable moderately susceptible species found at the Garden include: *Viburnum dilatatum* (Linden Viburnum) (Figure 8), *Viburnum farreri* (Fragrant Viburnum), *Viburnum carlcephalum* (Carlcephalum Viburnum), and *Viburnum rhytidophylloides* (Lantanaphyllum Viburnum) ("VLBCS: Susceptibility to Infestation," 2006).

Finally, *Viburnum* species categorized as "resistant species" are those that exhibit little or no feeding from the VLB and are never destroyed by an infestation. The resistant species found at the Garden include: *Viburnum rhytidophyllum* (Leatherleaf Viburnum), *Viburnum carlesii* (Korean Spice Viburnum), and *Viburnum pilicatum var. tomentosum* (Doublefile Viburnum) ("VLBCS: Susceptibility to Infestation," 2006).

The Viburnums share many similarities and sometimes are difficult to tell apart, especially when not in leaf, inflorescence, or fruiting. In addition to the native or "wild" species preferred by the VLB, there are many sub-species and cultivars of each individual species. However, the four *Viburnum* species that the NYBG is most concerned with, *Viburnum dentatum, Viburnum acerifolium, Viburnum opulus,* and *Viburnum dilatatum*, are more easily distinguishable.

As stated earlier, *V. dentatum* is highly susceptible to VLB infestation and a key target species of the Garden's control efforts. *Viburnum dentatum* has opposite, simple leaves that are rounded or wide-egg shape. The leaves are from 2 to 4.5 inches long and 1 to 4 inches wide and are short acuminate (end in a point). The edges of the leaves are coarsely dentate and are glabrous (smooth) on both sides. Leaf color can be lustrous dark green or just "plain" green depending on the variety (Figure 5). In the fall, leaves can range in color from yellow, to glossy red, to reddish purple. Leaf petioles range from 2/5 to 1- inch long. The stems are numerous and are long and straight at the bottom. When stems reach a certain height, they arch over on themselves forming a cascading effect; stems become glossy at maturity. *Viburnum dentatum* can grow from 6 to 15 feet tall and have a spread of 6 to 15 feet. The flowers are a creamy white color and bloom from May to early June in large clusters (Figure 5). The flowers make this shrub species very easy to spot in the forest. Fruits appear in large clusters of blue-black berries where the flowers were (Figure 9) ("VLBCS Guide to Identifying Viburnums: Arrowood Viburnum (*Viburnum dentatum)*," 2008. Dirr, 1983, p. 731).

Viburnum acerifolium is very unique, and although it may appear similar to *Viburnum opulus,* it is a much smaller shrub with noticeably different fruits. The leaves are 2 to 4 inches long and wide, opposite, simple, and three-lobed. The lobes are acute or acuminate and can be coarsely dentate. The leaves are slightly pubescent above and more pronounced on the bottom (Figure 7), bright green in the summer, turning reddish-purple in the fall. The leaf petiole is 2/5 to 1-inch long and also pubescent. The stem of the plant is similar to that of *Viburnum dentatum*. The shrub grows 4 to 6 feet tall and 3 to 4 feet wide. The flowers are yellow-white and bloom in early June (Figure 7). The fruits are black, egg shaped, and are very small (Figure 10) ("VLBCS Guide to Identifying Viburnums: Mapleleaf Viburnum (*Viburnum acerifolium)*," 2008. Dirr, 1983, p. 723).

Viburnum opulus/trilobum or European/American Cranberry Bush are both so similar that a common description can be given for both; most botanists no longer refer to them as two separate species. The leaves are opposite, simple, and three-lobed. They are 2 to 4 inches long and wide and are glabrous on the top with pubescent veins on the underside (underside can sometimes be glabrous as well). The leaves are a glossy dark green color in the summer time (Figure 6). In the fall, the leaves change to a yellow-red and reddish-purple. However, sometimes leaves do not change color and simply drop off while green. The leaf petioles are 2/5 to 4/5 inches long with a narrow groove and disklike glands. The stems are light gray-brown, smooth, and ribbed. The shrub grows from 8 to 15 feet tall and spreads from 10 to 15 feet. The flowers are small and white, forming in clusters (Figure 6). The fruits produced in place of the flowers are bright red berries (while they are ripening they are usually half yellow and half red) (Figure 11) ("VLBCS Guide to Identifying Viburnums: Cranberry Bush (*Viburnum opulus)*," 2008. Dirr, 1983, p. 738, 749).

Viburnum dilatatum is easy to distinguish from the others by nothing more than the way the leaves feel. The leaves are opposite, simple, and rounded or egg shaped. They are 2 to 5 inches long and 1 to 3.5 inches wide, hairy on both sides, and abruptly short acuminate (come to a sudden point). The edges of the leaves are coarsely toothed and dark green (sometimes lustrous) (Figure 8). In the fall, the leaves turn a brownish red color and stay on the plant late in the season. The petioles are 1/5 to 3/5 inches long. The twigs are hairy with prominent orange lenticels. The shrub is 8 to 10 feet tall and approximately the same spread growing mostly straight up. The flowers are creamy white and bloom in clusters in May to early June (Figure 8). The fruits are bright red and grow in clusters in place of the flowers (Figure 12) ("VLBCS Guide to Identifying Viburnums: Linden Viburnum (*Viburnum dilatatum)*," 2008. Dirr, 1983, p. 733).

My Work

Unfortunately, the New York Botanical Garden has not been spared from the rapid spreading of *Pyrrhalta viburni* infestation in New York State. As stated earlier, this work documents for the first time, the occurrence of VLB in Bronx County. The Horticulture Department of the NYBG is now developing a plan to control and hopefully eradicate the beetle at the Garden. In cooperation with Don Gabel (IPM Manager at the NYBG) and other members of the Horticulture staff of the NYBG, I have been conducting VLB surveys and inventorying damage to Viburnums throughout the Garden. Beginning in June 2009 through August 2009 (approximately 65 field hours), I performed a systematic reconnaissance (Appendix 1) to record and beetle life stages, *Viburnum* species distribution, and *Viburnum* infestation damage.

Mapping

In order assess the scale of VLB infestation at the Garden and also to make the final control plan more effective, the most vulnerable *Viburnum* species needed to be identified and locations plotted (see Appendix 1). To accomplish this, the NYBG was divided into 14 mapping zones. These zones include the more accessible and frequented public attraction areas, NYBG administrative and research buildings, greenhouses, as well as the targeted old growth forest area described earlier. As a first task, beginning in June, I conducted a more global survey of the grounds for the location of *Viburnum dentatum* and *Viburnum opulus* (*Viburnum acerifolium* was later added when a few shrub specimens were observed to be fed upon). This initial inventory quickly progressed to a more systematic and detailed survey of Viburnums once the main shrub groupings and more susceptible species were identified.

Damage Assessment

Last year, when the VLB infestation was first discovered by the NYBG, staff pruned the branches with observed eggs clusters on as many *Viburnum dentatum* specimens as possible. The goal of this year's study and my research was to conduct a more detailed *Viburnum* inventory and VLB damage assessment by Viburnum species. With a significantly greater and more complete accounting of the Viburnums this year, a comparison of the damage to last year's pruned shrubs to un-pruned shrubs was made in order assess the effectiveness of selective pruning as measure to reduce VLB infestation.

Working with Don Gabel, a damage rating system was created using a simple qualitative 0-5 Damage Assessment Scale (DAS):

- DAS Rating 0 = no visible VLB feeding damage;
- DAS Rating 1 to 2 = minimal visible VLB feeding damage, few and isolated eggs clusters present, *Viburnum* specimen considered healthy enough to fruit, flower, and return in the spring;
- DAS Rating 3 = moderate VLB visible feeding damage, moderate number of egg clusters, select branches and leaf clusters so heavily damaged (skeletonized) that they may die, but overall *Viburnum* specimen likely to recover in the spring;

- DAS Rating 4 = significant VLB feeding damage visible throughout the plant, skeletonized leaves very abundant, very high number of egg cluster sites, feeding damage so extensive that the *Viburnum* specimen may not recover in the spring;
- DAS Rating 5 = extensive and irreversible VLB feeding damage, almost every leaf has been skeletonized, almost every branch has a large number of eggs clusters, *Viburnum* specimen has been devastated with no chance of survival.

Equipped with the DAS ratings, a comparative VLB damage assessment was performed at five *Viburnum* sites that had been thoroughly pruned in 2008 and five *Viburnum* sites that had not been pruned in 2008. Upwards of three *Viburnum* specimens were examined in each of the five pruned and un-pruned areas and the damage assessed using the DAS system above. Once damage was assessed on individual *Viburnum* specimens within an area, each area was assigned a 0-5 DAS rating based on cumulative *Viburnum* specimen damage observed in that area. The numbers from each site were then averaged and compared to determine how effective the pruning method was.

Results

The first patch of pruned *Viburnum* shrubs I examined was located in **Zone 12** along a path on the south end of the Garden (Appendix 1). This area received a DAS rating of 1.0. Two patches in **Zone 9** were examined, one along the wetland path and another in the forest (Appendix 1). Both patches were assessed at a DAS rating of 2.0. Two more patches were examined in **Zone 3**, one at the sharp bend of the Oak Trail and another in the forest (Appendix 1). The Oak Trail patch received a DAS rating of 4.0 and the patch in the forest received a DAS rating of 2.0. The average DAS rating for the pruned *Viburnum* sites was estimated at 2.4.

Three patches of un-pruned *Viburnum* were examined in **Zone 3**; two of them at the Twin Lakes area and the third along the bank of the Bronx River to the left of Magnolia Way (Appendix 1). The leftmost Twin Lakes patch received a DAS rating of 2.0 and the rightmost patch received a DAS rating of 2.5. The patch along the riverbank received a DAS rating of 2.0. A single patch was examined in **Zone 6** in the forest behind the waterfall (Appendix 1) and received a DAS damage rating of 4.0. Finally, a single patch was examined in **Zone 9** in the forest (Appendix 1) and also received a DAS rating of 4.0. The average DAS rating for the un-pruned plant sites was estimated at 2.9. In general, infestation is heavier in the forest than out in the open. We also observed that smaller, more isolated plants were more damaged than larger, more heavily grouped plants.

Based on these results, we concluded that pruning of egg sites could be an effective form of VLB control for small patches of *Viburnum* or individual *Viburnum* plants. As such, this technique would be practical for a homeowner or landscape/garden center where only a handful of plants may have to be attended to. However, in an area as large as the NYBG (this applies to the broader landscape as well), pruning does not seem to be a very effective method since the pruned vs. un-pruned results were not significantly different. Additionally, with such a large area to manually prune, it's impractical to find and prune every specimen infested with VLB. From our experience, egg cluster sites are easy to miss. Depending on the size of the egg site, each one could produce between 8 and 340 new beetles (one egg cap holds up to 8 eggs and a large egg site could contain up to 40 egg caps). Missing even a few VLB egg sites in an area would leave a sufficiently large enough number of eggs in place to re-populate and re-infest the specimen as well as those Viburnums in the surrounding area

Observations

Pyrrhalta viburni adults were first observed in the NYBG on July 15, 2009 and the first eggs were identified on July 25, 2009. *Pyrrhalta viburni* greatly prefers the *Viburnum dentatum* complex to any other *Viburnum* at the Garden and among the *Viburnum dentatum* complex; VLB greatly prefers the native *Viburnum dentatum* to any of the subspecies or cultivars. Further, my results showed that *Pyrrhalta viburni* only crosses over to a new species of *Viburnum* when the new species is in close proximity to a heavily damaged patch of *Viburnum dentatum*. Crossover can occur when larvae crawl across overlapping leaves or when the more mobile flying adults migrate to better feeding grounds.

The observations at the NYBG are consistent with published results by other VLB investigators in New York State (Cornell University Department of Horticulture, 2009, p. 7., Hanau, 2008).

Significance of My Work

The *Pyrrhalta viburni* infestation at the NYBG, as with any invasive species, is a significant issue that requires immediate attention before its population becomes unmanageable and the ecological damage irreversible. This VLB study is very likely a first stage of what will be a large and most likely long-term project at the NYBG. The results of this VLB study build upon preliminary VLB infestation observations by staff of the NYBG during the previous growing season. My work resulted in a comprehensive mapping and speciation of Viburnums throughout the Garden, and recordation of the emergence of VLB life stages by month, *Viburnum* species, and NYBG zone (Zones 1-14 (Appendix 1)). Subsequent to my mapping of VLB infestation and *Viburnums* at the Garden, development of a simple damage rating scale (DAS) enabled a comparison of *Viburnum* sites subjected to a 2008 pruning control method with those sites that were un-pruned.

My results enabled a qualitative, yet valid, conclusion regarding the effectiveness of this technique over an area as large and diverse as the NYBG. Albeit seemingly effective on a localized scale, the labor intensity involved with pruning combined with the significant potential that not all egg sites can be located and pruned leads to the conclusion that some other control method is better suited for the Garden's particular size and setting. Given the widespread distribution of VLB at the NYBG, it is likely that without stepped-up and more aggressive management controls, at least the native varieties of *Viburnum* (particularly *V. dentatum*) could be eliminated in just a few growing seasons. Lastly, my work adds significantly to the growing body of VLB information in the literature, and, for the first time, documents the presence of *Pyrrhalta viburni* in Bronx County, New York.

Dealing with Invasive Species Problems

In the last 200 years, North America has been invaded by over 70 species of fish, 80 species of mollusk, 2,000 species of plants, and 2,000 species of insects (Ricklefs, 2007, p.490). Invasive species are almost never beneficial to a native habitat and the indigenous species. One exception is the Asian Oyster, which is much better at filtering water pollutants, faster growing, and more disease resistant than our native oysters. It is being considered for use in restoring the oyster population and water quality of the Chesapeake Bay ("Invasive Species", 2009).

In addition to environmental costs, an invasive species can also be economically expensive due to the costs of agricultural and forestry production loss, the price of managing a new invasive species, and loss of recreational and tourism revenues. It is estimated that invasive species cost the United States $138 billion each year ("Invasive Species", 2009).

Invasive species, be they plant or animal, are often terribly destructive and in extreme cases, can completely destroy the natural landscape beyond the point of natural recovery. It is even possible for an invasive species to alter the function of an ecosystem by changing the fire regime, nutrient cycle, hydrology, by hybridizing with closely related native species, leading to genetic pollution and potential extinction of the native species, and much more ("Invasive Species", 2009). What makes an invasive species so problematic is the mismatch of adaptations that we usually find between native and invasive species. This adaptive mismatch affords the invasive species a huge advantage over native species. Almost all invasive species share some or all of the following characteristics:

- A high reproductive rate;
- Highly competitive for resources;
- Are able to grow and flourish in diverse habitats;
- Fill certain niches that have been previously unoccupied (lack of competition);
- Exhibit a higher tolerance for human-altered environments and variable environmental conditions (broad tolerance level);
- Invade habitats that are similar to their native environment;
- Have few or no natural predators.

In a hypothetical example, a small island contains a species of flightless bird. This bird lives on the ground feeding mostly on insects. It has no real predators aside from the occasional stray cat so being flightless is no disadvantage to the bird. Somehow, a large carnivorous species of lizard is introduced to the island from another country. They are quick, well camouflaged, and because they are from another country and another habitat, they have no predators in this new isolated habitat. They develop a taste for this native flightless bird because the birds are plentiful and easy to catch. In about a year, the bird population is heavily damaged and the lizard population is thriving and growing due to the plentiful food source, lack of predators, and isolated habitat. Without some sort of intervention, these lizards will extinguish the bird population.

Many of the areas that are most severely affected by an invasive species are isolated islands where an invasive organism has been introduced. The native species are almost always poorly adapted to survive with this new invasive species (Ricklefs, 2007, p.490). The aforementioned hypothetical example also applies to the NYBG and VLB. Some of the worst invasive species outbreaks and results happen in isolated environments such as the NYBG. In a sense the NYBG is an "island", a green oasis in an otherwise sterile, concrete landscape. As an island refuge within a predominantly urban environment, VLB infestation at the NYBG could track along a similar pattern. The damage to *Viburnum* could be irreversible as it has no defense and can't adapt fast enough to the stress exerted by VLB.

Once an invasive species is established, it can be very difficult and expensive to control. Often times, it can't be completely eliminated but only managed to a level that averts the extinction of a native species or collapse of a natural ecosystem. The difficulty is that the invasive species must be removed or its numbers controlled without further damaging the native environment. Introducing another new species to biologically control the invasive species (typically a predator from the host country) is a common but risky practice. With any introduced species, it must be assured that the control species will be effective and "targeted" at the invasive species while at the same time, not likely become a pest itself. Some examples of successful species introduction include two species of beetles in the genus *Galerucella* (Purple Loosestrife Beetle) that feed voraciously on another invasive species of wetland grass called Purple Loosestrife (*Lythrum salicaria)* (A. Russo, personal communication, Nov 23, 2009). Chemical control methods such as insecticides are not usually favorable because if used irresponsibly there is a high probability of harming and polluting a large number of native plant and animal species along with the invasive species.

Beyond the obvious ecological and conservation reasons for implementing a VLB control program, the NYBG has added social and economic incentives for striving to control and hopefully eliminate the VLB due to the fact that their collections of plants are what draw the visitors that support the continued education, research and conservation efforts of the Garden.

Future Steps

Discovery of VLB infestation at the NYBG is coincidentally timed with the beginning of the Garden's aforementioned forest restoration project, adding another very large project to an already long list of goals to accomplish. Nonetheless, the results of my work on the VLB in 2009 will enable Garden staff to plan an expansion of the control program in 2010, coordinated with other forest restoration activities. Preliminarily, the Garden's Department of Horticulture and IPM Manager, Mr. Don Gabel, has developed several alternative control solutions to the VLB infestation problem. Each will be tested in different areas of the Garden and the results compared to determine which control method is most effective and most economical. The options under consideration are as follows:

One option is to simply continue to prune egg sites in the late summer, fall, and winter. This has proven to be somewhat effective in select areas, but in order for it to have any significant effect, it must be done thoroughly throughout the entire area. As mentioned earlier, pruning is very labor intensive and alone, is not likely an effective plan for an area as large as the NYBG.

Another option involves application of pesticides. The Garden wants to avoid this option if possible since pesticides, when used irresponsibly pose a risk to native insect species (some of which could serve as VLB predators) as well as humans and other animals. Most pesticides contain what are called contact poisons, meaning they kill the insect upon contact and must be administered directly to the plant while the insects are on it. The negative aspect of this method is that these contact poisons can kill beneficial insect species that would otherwise help to control the beetles. Pesticides may also kill other beneficial insect species that are controlling a totally different pest and lead to a secondary pest outbreak (Don Gabel, NYBG IPM Manager, personal communication, November, 18 2009). Frequent pesticide use can also lead to pesticide resistant individuals leading to decreased pesticide efficiency and the need to use larger amounts of pesticide. Also, timing is a key factor. The younger the insects are (early larval stage) the more effective the insecticide will be, so application must be timed relatively well with egg hatch ("VLBCS: Managing Viburnum Leaf Beetles," 2006).

Horticultural oils have been found to be an effective method for killing the eggs. It is sprayed onto the egg sites and has been found to reduce hatching by 75-80%. However it must be sprayed before leaves emerge as it has a tendency to burn leaves ("VLBCS: Managing Viburnum Leaf Beetles," 2006).

A study done by the Cornell University Department of Entomology found that application of certain insecticides to the soil and trunks (systemic pesticide) of *Viburnum* was the most effective insecticidal treatment against VLB. The research team discovered no larvae on the treated plants. This control technique was found to be more effective against leaf damage because unlike treatments that are applied directly to the leaves, soil and stem applications are administered before any larvae emerge. Soil applied insecticides were also found to be less of a threat to natural predators of the beetles as well as other non-target insect species. This type of treatment also spares non-target organisms because it can be applied at a time when there are very few active arthropods. Soil pesticide use was found to be effective up to one year after application (Weston, P. A., et al. p. 82-85).

Introducing more predatory species is another option. Insects like Lacewings and Ladybugs have been known to feed on VLB larvae. Also, species of soil nematodes (non-segmented roundworms) have also been found to be highly effective in reducing adult soil emergence. In another study done by the Cornell University Department of Entomology, researchers found that the Ladybird Beetle *Harmonia axyridis* (in the adult stage) and the larvae of *Chrysoperla carnea* (Green Lacewing) could be good candidates for biological control of VLB. *H. axyridis* in its adult stage was found to be highly effective against the beetle larvae. However, in the wild it seems to prefer feeding on aphids instead of beetle larvae. *C. carnea* in its larval stage was found to be effective only against 1st instar larvae since the 3rd instar larvae seemed to be too big for the *C. carnea* larvae to handle. Researchers also tested a species of parasitic nematode named *Heterorhabditis bacteriophora* that attacks insects in the soil. They found this to be the most promising method of biological control as it reduced VLB adult emersion from 74% to 12% (Weston, P. A., et al. p.1-4).

It may also be possible to trap larvae and emerging adults as they crawl up and down the plant to and from the soil. A company called Tanglefoot produces "chemical free methods of pest management for both home orchards and commercial horticultural operations," ("Tree Tanglefoot Pest Barrier" 2002). One product in particular called "Tree Tanglefoot Pest Barrier" is specifically meant for insects that crawl up and down plants to feed, mate, and lay eggs. Such a product could be an effective control method. The disadvantage of this method is that Tanglefoot Pest Barrier must be applied manually, therefore it is highly labor intensive, especially since *Viburnums* are comprised of several small trunks rather than one large one. This method could be a very useful one for the Garden's ornamental *Viburnums* ("Tree Tanglefoot Pest Barrier" 2002).

A final, last resort option, especially for heavily infested areas, is to simply cut all of the *Viburnum* down to the base. This would ensure that all of the eggs have been removed and that any adults that emerge will have nowhere to go. In essence, their life cycle would be interrupted. This is the least desirable control option and should be reserved for only the most severe circumstances. First, all the plants will not grow back if they are cut to the base, and if one of the goals of the forest restoration project is to add more *Viburnum dentatum* then this is a counterproductive measure. Third, if any plants are overlooked and contain eggs, it is highly possible that the infestation could begin all over again. Considering all of these points together: VLB is far more devastating on younger plants than mature plants; un-cut plants that are left behind enable more beetles to survive and reproduce perhaps with increased intensity; VLB that survive will ravage any new *Viburnum* growth; and, *Viburnums* that have been cut back will not recover.

Cutting also creates other problems like: enhancing erosion once groundcover is removed; opens "holes" in the forest floor that could be occupied with a non-native plant; wildlife that depend on Viburnums are deprived which could have other food chain and ecosystem effects. These effects could be mitigated by planting other native, VLB resistant species in their place right away as part of the forest restoration.

Broad Evaluations

What My Work and Experience with the Garden Means for Me

My long-term goal after college is to pursue a professional career in environmental science and conservation biology. The NYBG was a perfect place for me to gain real experience in the conservation field, since one of their major goals is conservation of not only the local landscape that comprises the Garden, but the study and conservation of plant species, ecosystems, and biodiversity around the world. I feel especially fortunate to be able to work on species conservation right at the doorstep of Fordham University and in the heart of the Bronx. In addition, I feel a sense of accomplishment in being the first to document the presence of *Pyrrhalta viburni* in Bronx County as well as Putnam County, New York. After researching how quickly VLB has spread throughout the New York State and the Northeast region, and personally studying its effects not only at the Garden, but also at a local nature preserve (Ice Pond Preserve, Putnam County, NY) near my home, I immediately realized the importance of controlling this species before it can become even more devastating than it already is. I felt a great sense of satisfaction and importance while working with the Garden staff on a plan for controlling VLB and preserving the native *Viburnum* of the NYBG. I look forward to working on the next phase of the control program and forest restoration project.

How My Work Affected My Understanding of Environmental Policy, Values, and Science

In the field of biological conservation, three goals are commonly sought after: The management of game species for sustained yield, the conservation of examples of endangered or threatened species, and, most relevant to my work, the preservation of balanced populations of species in their native habitats. This third goal not only seeks to preserve species but also the ecosystem in which they live. This goal not only preserves populations, but also the processes that identify the interactions between species and the environment (Westman, 1985, p.73). In general, the most basic way to maintain a population of a species is to guarantee the existence of enough area of suitable habitat and that this area is kept free of invasive competitors, predators, and diseases (Ricklefs, 2007, p.493).

My internship experience in 2009 has helped me to better understand how many factors from different areas of expertise must be considered when working on a conservation project. Environmental science, ecology and conservation biology are truly multidisciplinary spanning not just the classic sciences, but economics, regulatory policy and planning, and education. Experts with experience in economics must determine the cost of the project and, determine the best balance between cost and effectiveness. This is typically done with cost/benefit analysis calculations. (Westman, 1985, p.180) This calculation takes into account the cost of damage, repair, and replacements. Factors that must be considered in this are cost of materials and labor as well as the duration of the project. Scientists, specifically conservation biologists, must look at the proposed project and determine what effects it may have on non-target species and habitats. Although all species are important to the environment and must be preserved, scientists must determine the role that the threatened species plays in its environment and judge its relative importance. In addition, all parties must work together to ensure that the project is done in a way that does not violate environmental laws or standards of practice.

Personal Priorities for Future Study and Career Development

My first priority is to finish my undergraduate BS degree in Environmental Science and Environmental Studies. During that time I hope to gain another internship or research position at the NYBG, the Bronx Zoo, or the Fordham University Calder Research Center and be able to carry this work over into graduate school. I plan to start graduate school immediately after finishing my undergraduate degree. While in graduate school, my intent is to pursue a specialization in ecology or conservation biology and hopefully conduct related research at the same time. Post-graduate school, I would like to pursue a career in the field of habitat conservation and/or restoration using the knowledge and experience gained throughout my academic studies and research.

What should be the future mission of the New York Botanical Garden?

I believe that the current mission of the New York Botanical Garden is laudable. The mission to preserve natural habitats, document the world’s plant species, conduct plant research, educate the public, and house one of the most extensive botanical records has made them one of the leading institutions for botany and horticultural science in the world. As a future goal, while maintaining their core mission, the Garden can expand and seek to improve green facility programs and sustainability practices. In addition, the Garden should seek to publicize the scientific research and conservation projects of their many scientists and make this information more accessible to the public. Also, as an institution that is so devoted to conservation, the Garden should offer to the public more public education sessions during daily visiting hours, in addition to classroom courses, educate everyday visitors and children about environmental conservation and environmental science.

Table of Figures

Figure 1: Seed Collection in Old Growth Native Forest

Gregory A. Russo, October 2009

Figure 2: VLB Egg Sites on New Growth

Paul Weston, http://www.hort.cornell.edu/vlb/images/neweggs600.jpg, October 2006

Figure 3: Larvae Feeding on a Nearly Skeletonized Leaf

Gregory A. Russo, June 2009

Figure 4: Adult Beetles Next to Feeding Damage

Kent Loeffler, http://www.hort.cornell.edu/vlb/images/adultsfeedinglg.jpg, October 2006.

Figure 5: *Viburnum dentatum*

http://www.missouriplants.com/Whiteopp/Viburnum_dentatum_page.html

Figure 6: ***Viburnum opulus/trilobum***

http://www.plant-identification.co.uk/skye/caprifoliaceae/viburnum-opulus.htm

Figure 7: ***Viburnum acerifolium***

Gregory A. Russo, June 2009

Figure 8: ***Viburnum dilatatum***

http://www.mobot.org/gardeninghelp/images/low/C355-0628050cs.jpg

Figure 9: ***Viburnum dentatum*** **Fruit**

Jack Scheper, http://www.floridata.com/wallpaper/jpg/Viburnum_dentatum800.jpg, 2003

Figure 10: ***Viburnum acerifolium*** **Fruit**

Albert F. W. Vick, http://www.wildflower.org/gallery/result.php?id_image=2701, June 1991

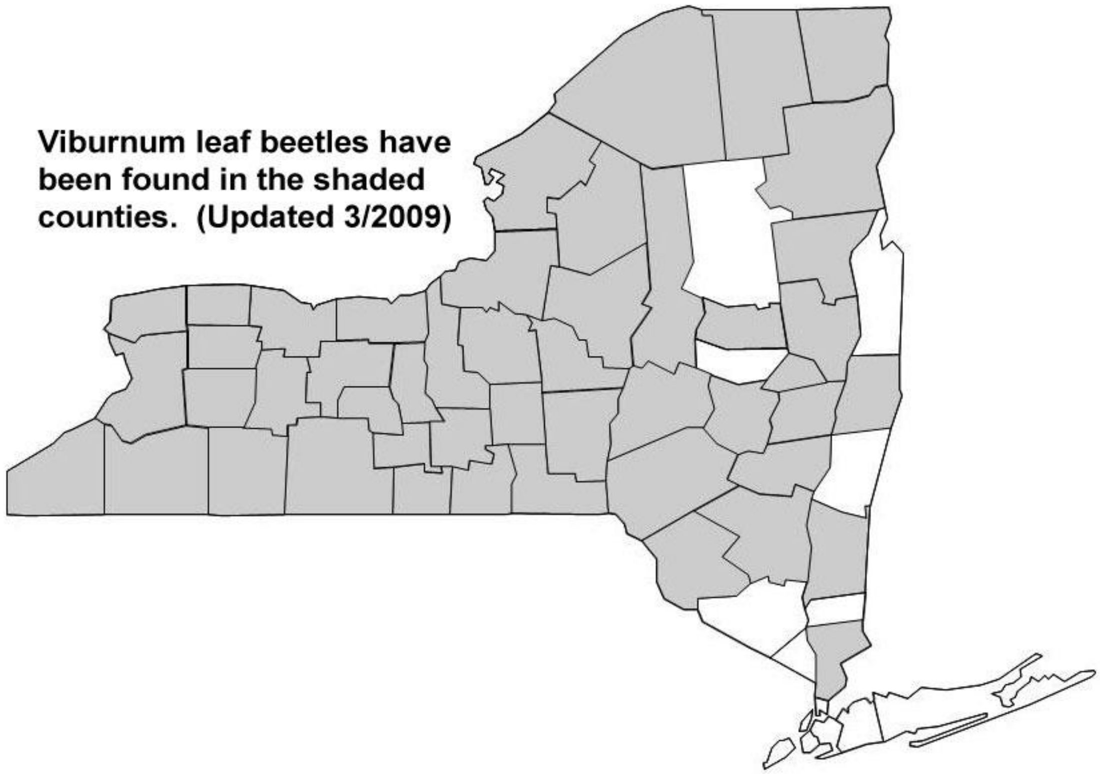
Figure 11: ***Viburnum opulus/trilobum*** **Fruit**

Gregory A. Russo, September 2009.

Figure 12: ***Viburnum dilatatum*** **Fruit**

Gregory A. Russo, October 2009.

Figure 13: ***Pyrrhalta viburni*** **Distribution in New York State**



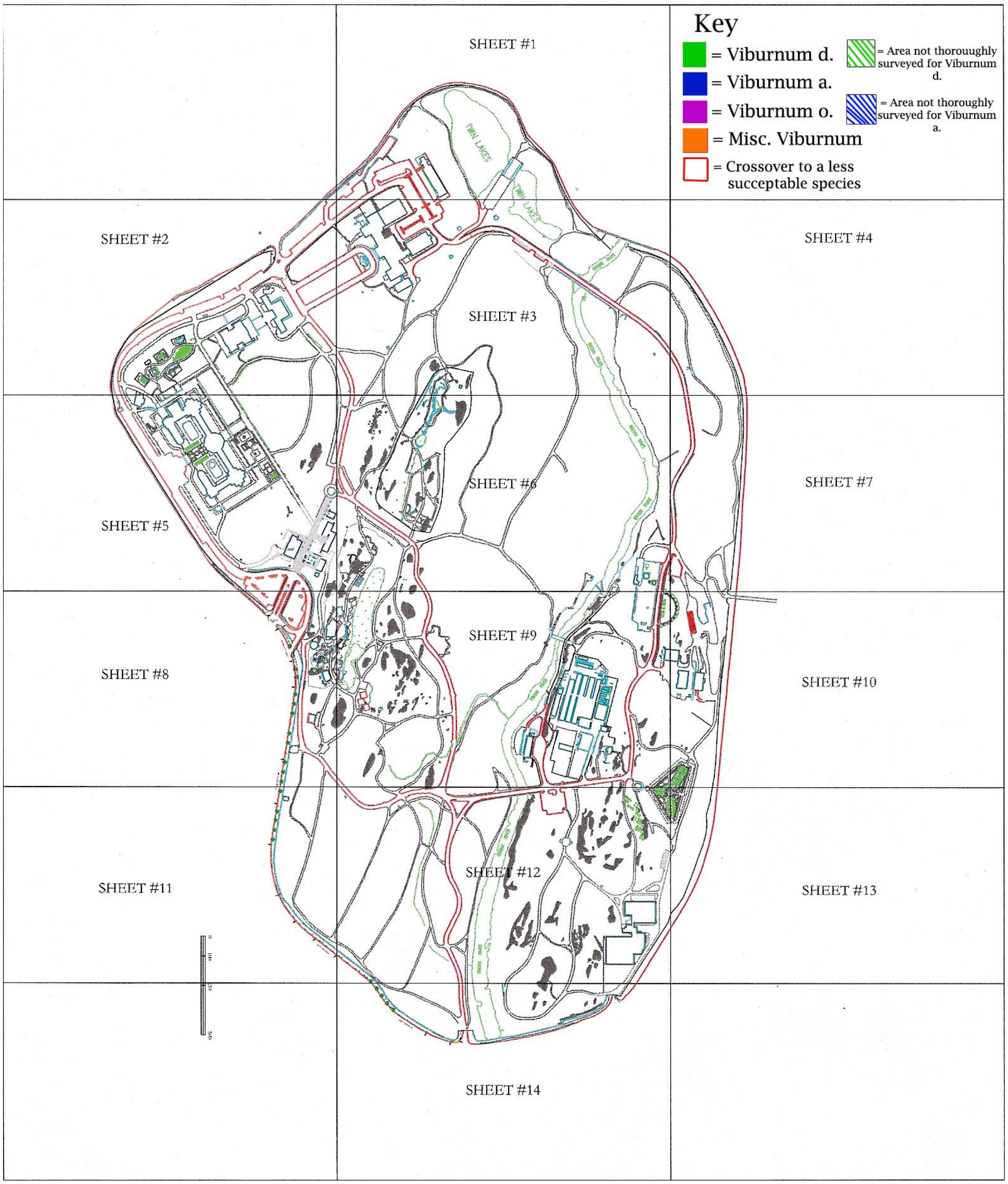
Cornell University, Department of Horticulture, 2009

Figure 14: DAS Survey Data

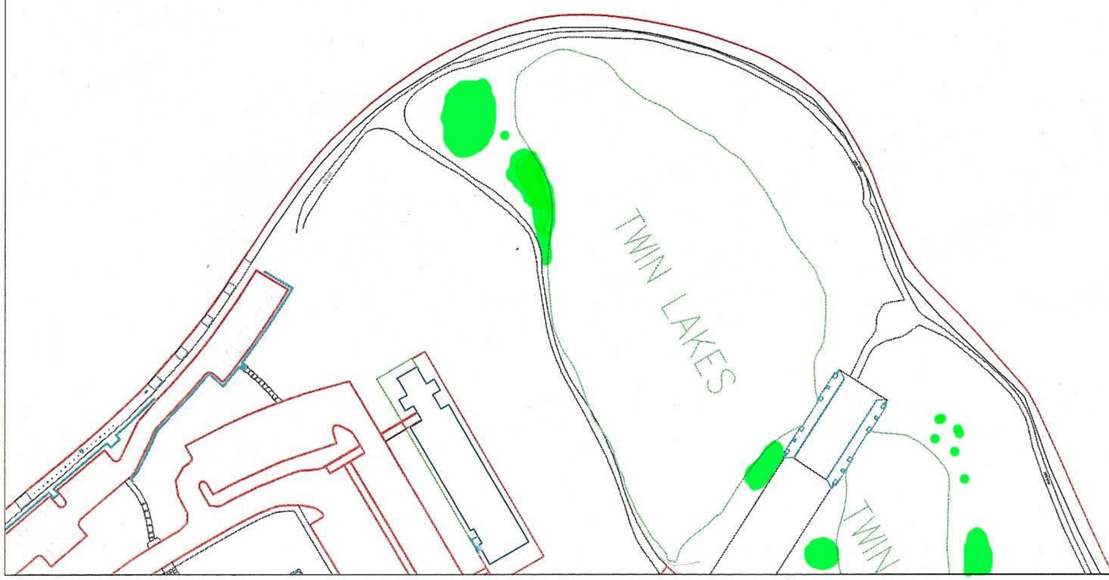
	DAS Survey Patch 1	DAS Survey Patch 2	DAS Survey Patch 3	DAS Survey Patch 4	DAS Survey Patch 5	DAS Average
Pruned	1.0	2.0	2.0	4.0	2.0	2.4
Un-Pruned	2.0	2.5	2.0	4.0	4.0	2.9

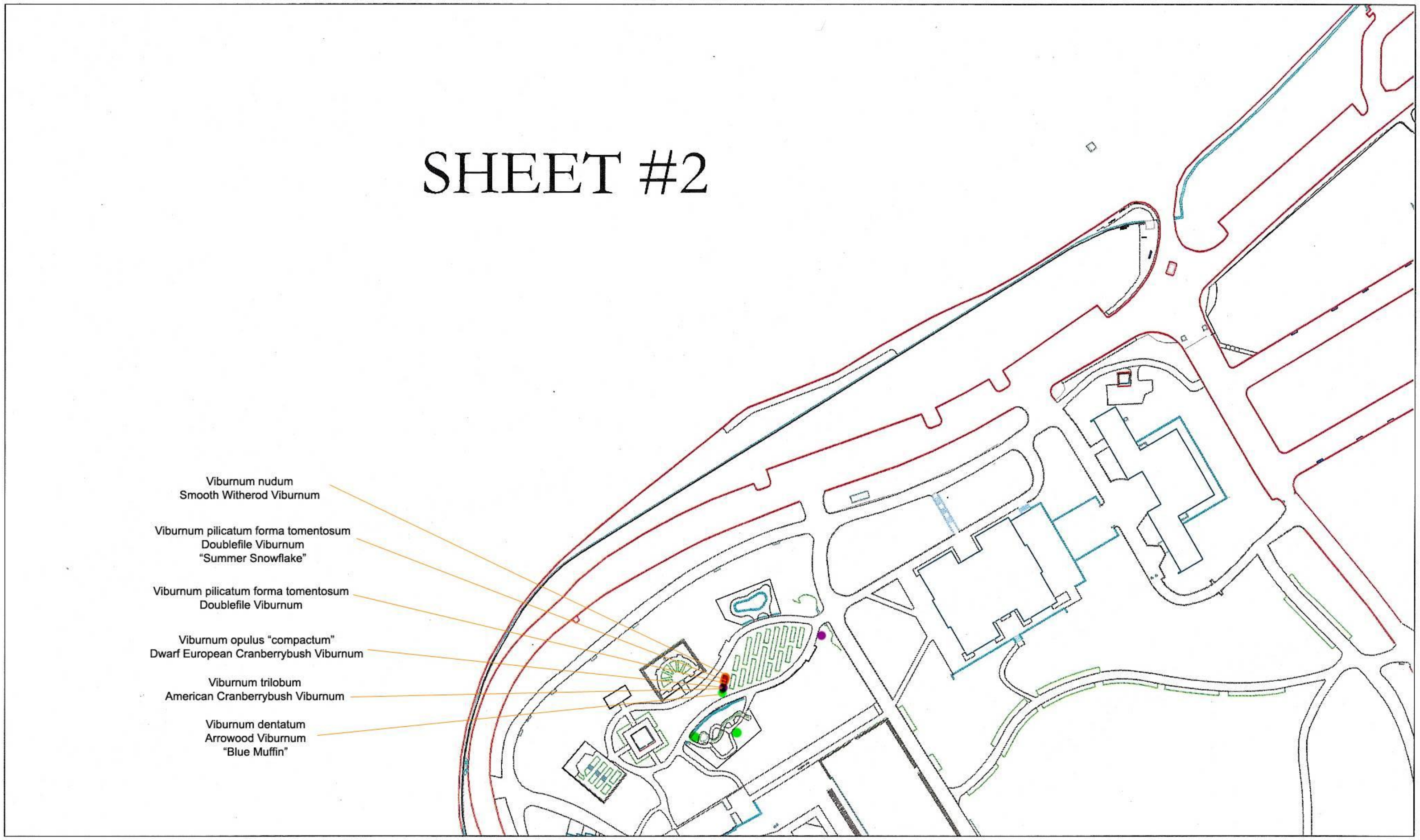
Appendices

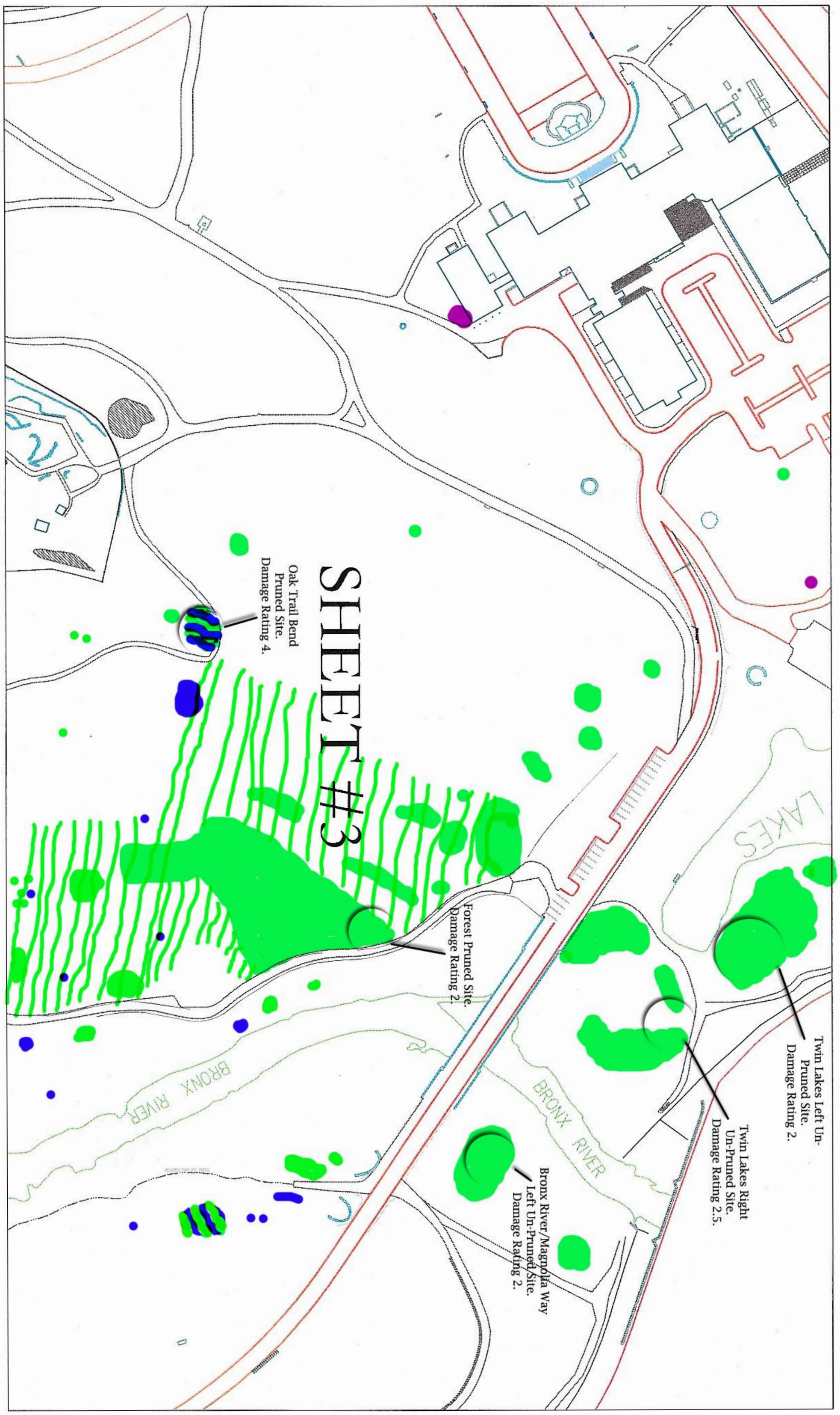
Appendix 1: Maps



SHEET #1

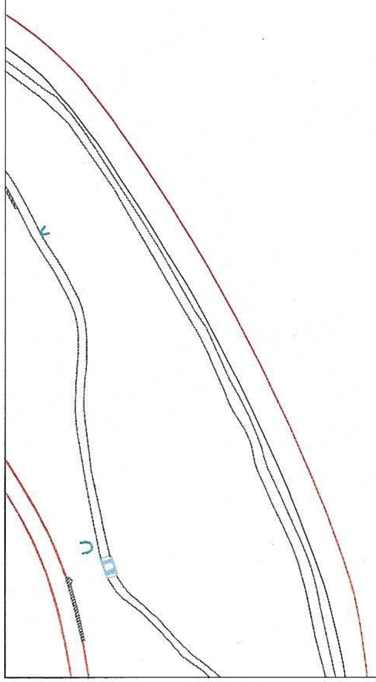


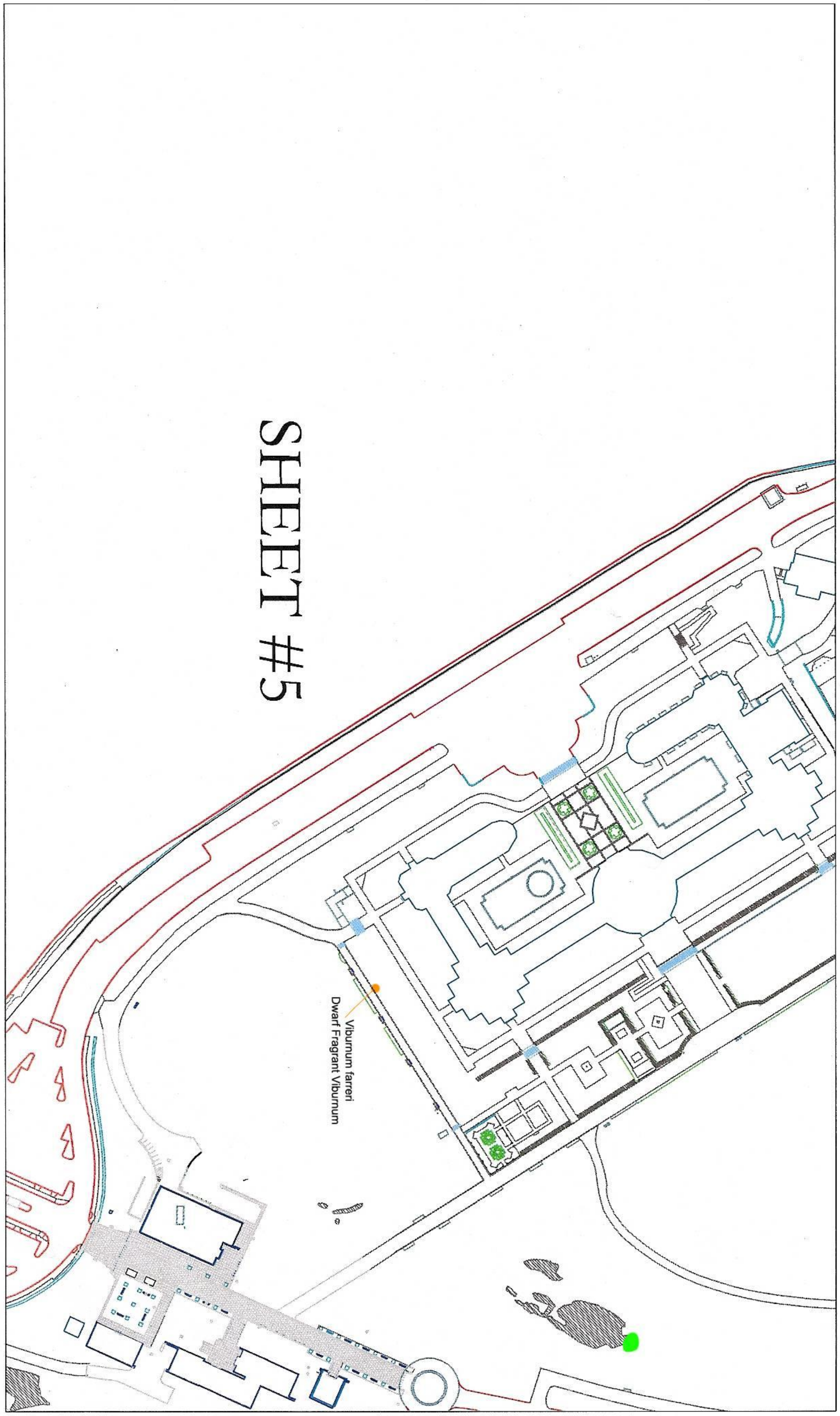

SHEET #2
Viburnum nudum
Smooth Witherod Viburnum
Viburnum pilicatum forma tomentosum
Doublefile Viburnum
"Summer Snowflake"
Viburnum pilicatum forma tomentosum
Doublefile Viburnum
Viburnum opulus "compactum"
Dwarf European Cranberrybush Viburnum
Viburnum trilobum
American Cranberrybush Viburnum
Viburnum dentatum
Arrowood Viburnum
"Blue Muffin"

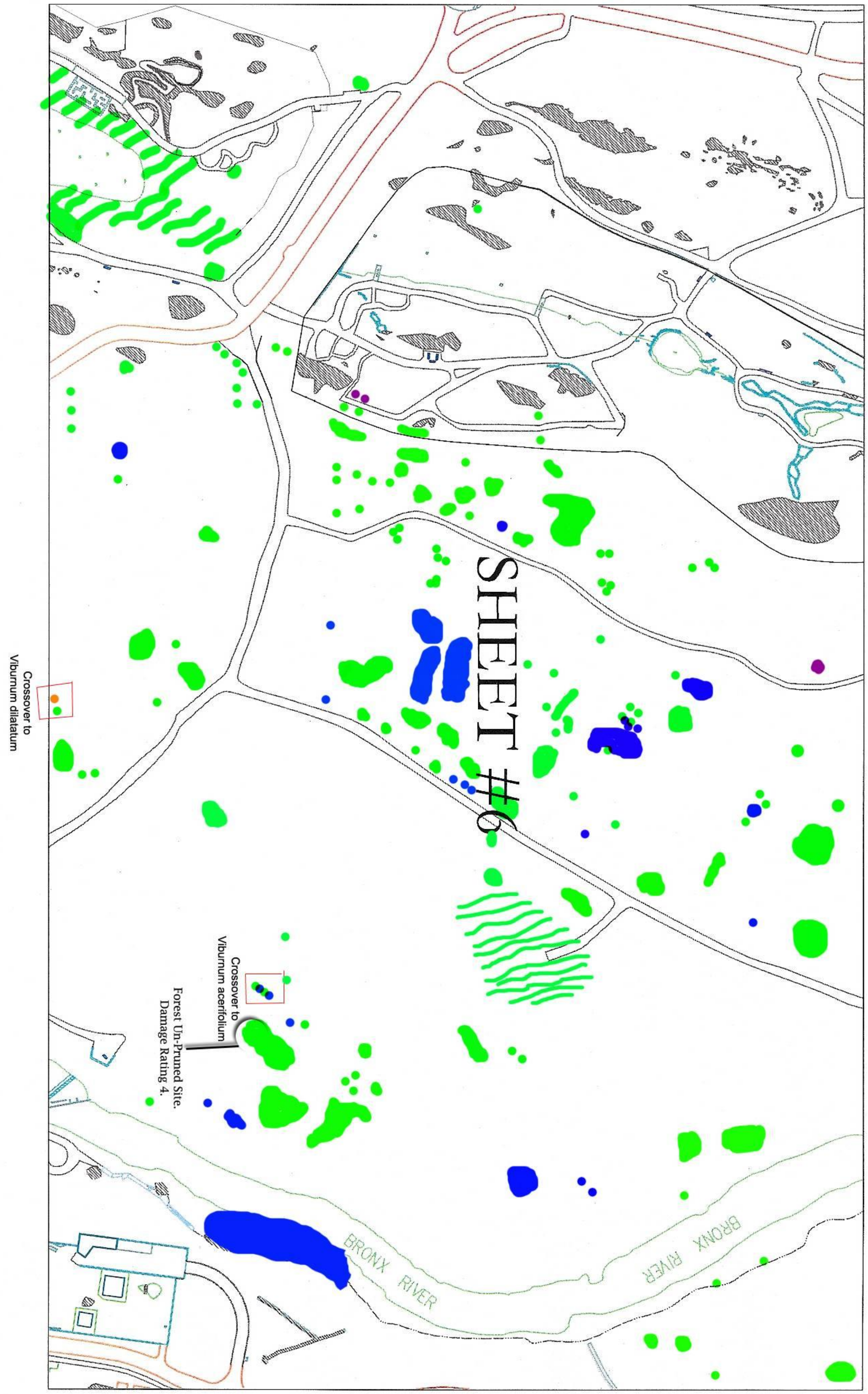

SHEET #3
Oak Trail Bend
Pruned Site.
Damage Rating 4.
Forest Pruned Site.
Damage Rating 2.
Twin Lakes Left Un-
Pruned Site.
Damage Rating 2.
Twin Lakes Right
Un-Pruned Site.
Damage Rating 2.5.
Bronx River/Magnolia Way
Left Un-Pruned Site.
Damage Rating 2.
BRONX RIVER
BRONX RIVER
LAKES

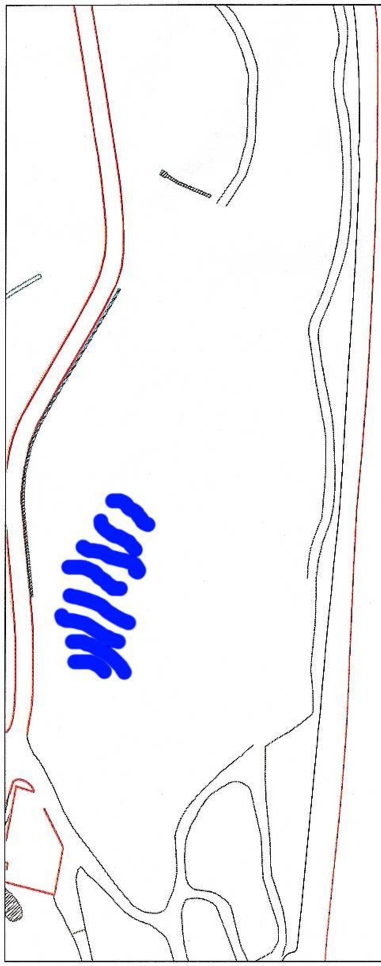
SHEET #4

No Viburnum dentatum found in this area.



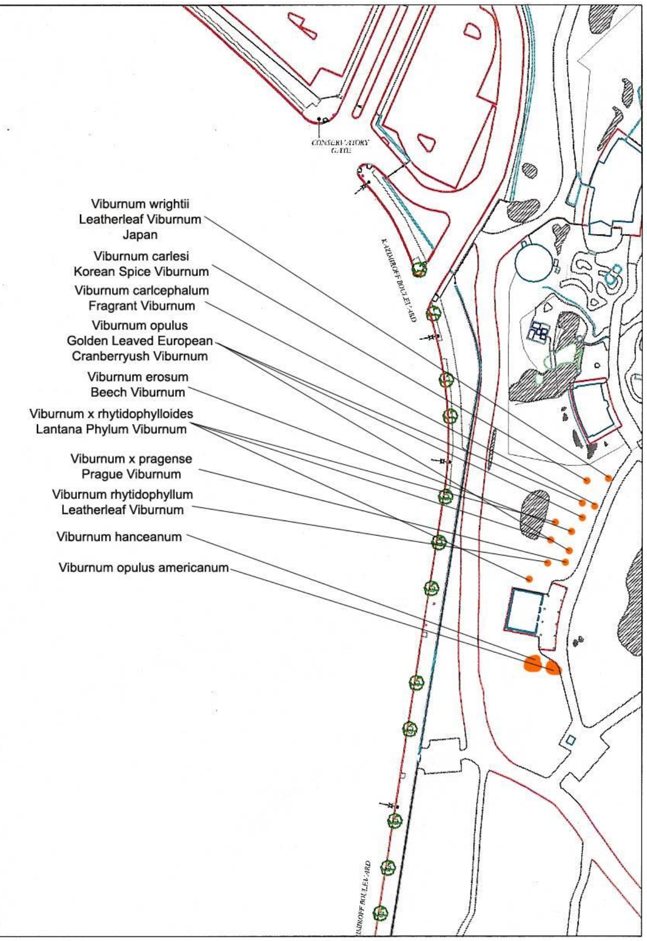

SHEET #5
Viburnum farreri
Dwarf Fragrant Viburnum


SHEET #6
Crossover to Viburnum dilatatum
Crossover to Viburnum acerifolium
Forest Un-Pruned Site.
Damage Rating 4.
BRONX RIVER
BRONX RIVER

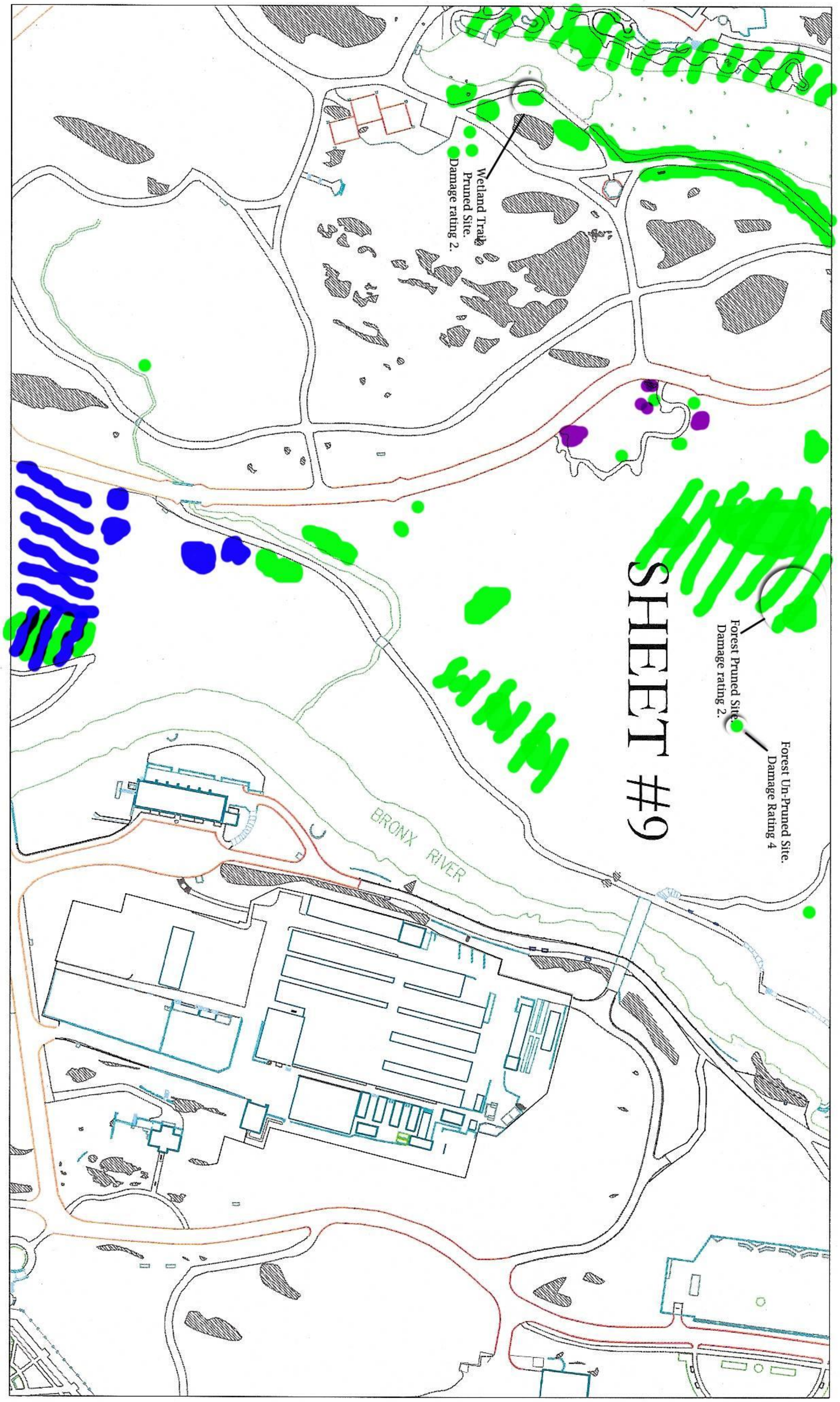


SHEET #7

SHEET #8

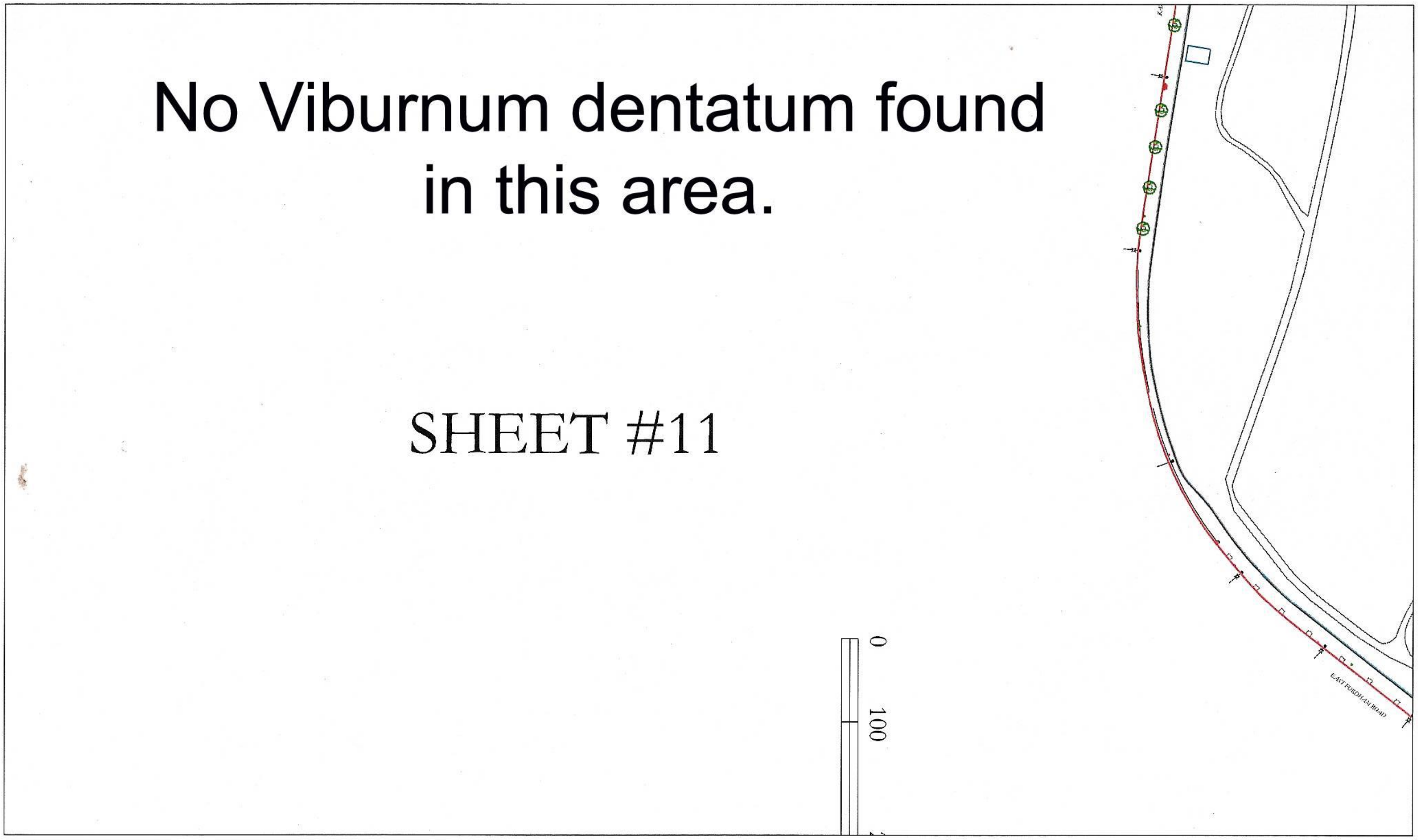


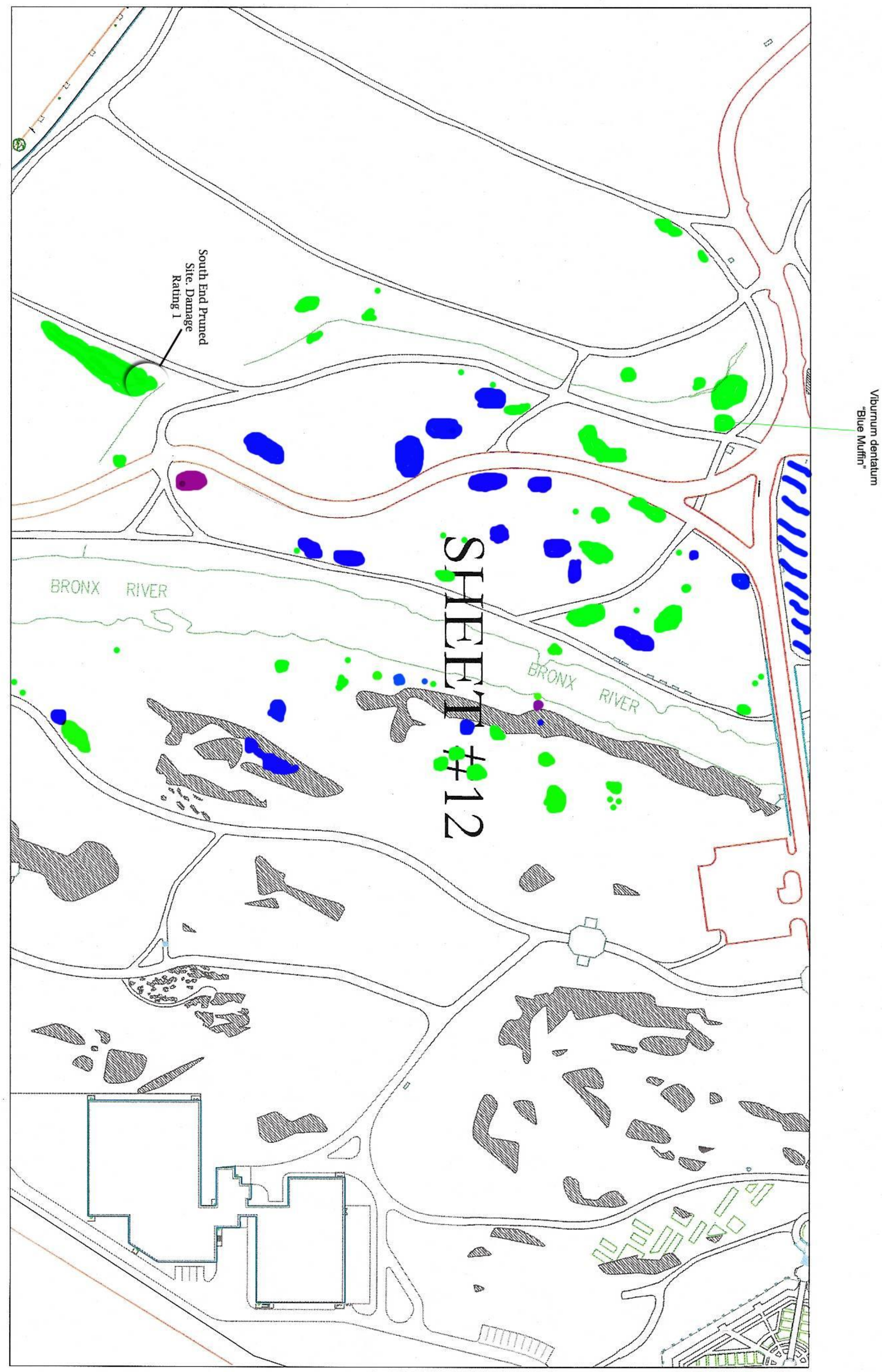
CONSERVATORY GATE
Viburnum wrightii
Leatherleaf Viburnum
Japan
Viburnum carlesi
Korean Spice Viburnum
Viburnum carlcephalum
Fragrant Viburnum
Viburnum opulus
Golden Leaved European
Cranberryush Viburnum
Viburnum erosum
Beech Viburnum
Viburnum x rhytidophylloides
Lantana Phylum Viburnum
Viburnum x pragense
Prague Viburnum
Viburnum rhytidophyllum
Leatherleaf Viburnum
Viburnum hanceanum
Viburnum opulus americanum

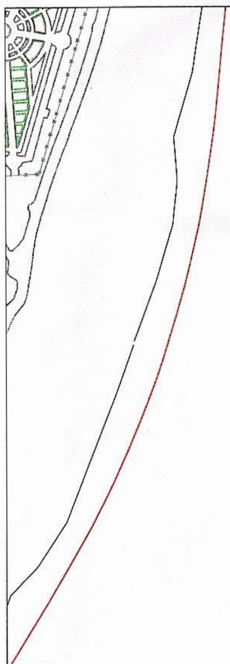

SHEET #9
Wetland Trail Pruned Site. Damage rating 2.
Forest Pruned Site. Damage rating 2.
Forest Un-Pruned Site. Damage Rating 4
BRONX RIVER

SHEET #10

No Viburnum dentatum found in this area.


No Viburnum dentatum found in this area.
SHEET #11
0
100
EAST FORDHAM ROAD


South End Pruned Site. Damage Rating 1
Viburnum dentatum "Blue Muffin"
SHEET #12
BRONX RIVER
BRONX RIVER



No Viburnum dentatum found
in this area

SHEET #13

SHEET #14

Works Cited

Cappobianco, C., (2009, September). *Garden Receives Funding for Bronx River Protection*. Retrieved October 26, 2009, from http://www.nybg.org/wordpress/?p=3850

Cornell University Department of Horticulture. (2009, August). Susceptibility to Infestation by Viburnum Leaf Beetle. *Long Island Horticulture News*, 7.

Dirr, M. A., (1983). *Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation, and Uses.* Champaign: Stipes Publishing Company.

Hanau, N., (2008, August). *Viburnum Leaf Beetle: An IPM Report*.

Loeffler, K., Weston, P., & Cramer, C. (n.d.). *Viburnum Leaf Beetle: Citizen Science*. Retrieved October 26, 2009, from http://www.hort.cornell.edu/vlb/index.html

Loeffler, K., Weston, P., & Cramer, C. (2006, October). *Viburnum Leaf Beetle Citizen Science: Managing Viburnum Leaf Beetles*. Retrieved October 26, 2009, from http://www.hort.cornell.edu/vlb/manage.html

Loeffler, K., Weston, P., & Cramer, C. (2009, March). *Viburnum Leaf Beetle Citizen Science: The Pest*. Retrieved October 26, 2009, from http://www.hort.cornell.edu/vlb/pest.html

Ricklefs, R. E., (2007). *The Economy of Nature*. New York: W.H. Freeman and Company

Swaciak, D., & Eames-Sheavly, M., (2008, April). *Viburnum Leaf Beetle Citizen Science Guide to Identifying Viburnums: Mapleleaf Viburnum (Viburnum acerifolium)*. Retrieved October 26, 2009, from http://www.hort.cornell.edu/vlb/key/Vacer.html

Swaciak, D., & Eames-Sheavly, M., (2008, April). *Viburnum Leaf Beetle Citizen Science Guide to Identifying Viburnums: Linden Viburnum (Viburnum dilatatum)*. Retrieved October 26, 2009, from http://www.hort.cornell.edu/vlb/key/Vdila.html

Swaciak, D., & Eames-Sheavly, M., (2008, April). *Viburnum Leaf Beetle Citizen Science Guide to Identifying Viburnums: Arrowood Viburnum (Viburnum dentatum)*. Retrieved October 26, 2009, from http://www.hort.cornell.edu/vlb/key/Vdent.html

Swaciak, D., & Eames-Sheavly, M., (2008, April). *Viburnum Leaf Beetle Citizen Science Guide to Identifying Viburnums: Cranberry Bush (Viburnum opulus)*. Retrieved October 26, 2009, from http://www.hort.cornell.edu/vlb/key/Vopul.html

Weston, P. A., Eshenaur, B., & Lamboy, J. S., (n.d). *Biological Control of Viburnum Leaf Beetle.*

Weston, P. A., Eshenaur, B., Baird, J. M., & Lamboy, J. S., (2002). Evaluation of Insecticides for Control of Larvae of *Pyrrhalta Viburni*, a New Pest of Viburnums. *Journal of Environmental Horticulture*, 20(2), 82-85.

Weston, P., (2006, October). *Viburnum Leaf Beetle Citizen Science: Susceptibility to Infestation*. Retrieved October 26, 2009, from http://www.hort.cornell.edu/vlb/suscept.html

Westman, W. E., (1985). *Ecology, Impact Statement, and Environmental Planning.* New York: John Wiley & Sons.

(November 27, 2009). *Invasive Species.* Retrieved November 30, 2009, from http://en.wikipedia.org/wiki/Invasive_Species

(n.d.). *About The Garden.* Retrieved October 26, 2009, from http://www.nybg.org/explore_and_learn/about_the_garden.php

(n.d.). *Education: Public Education for Children and Adults.* Retrieved October 26, 2009, from http://www.nybg.org/explore_and_learn/education.php

(n.d.). *International Plant Science Center: Field Research.* Retrieved October 26, 2009, from http://sciweb.nybg.org/science2/FieldResearch.asp

(n.d.). *Mission and History.* Retrieved October 26, 2009, from http://www.nybg.org/explore_and_learn/mission_and_history.php

(n.d.). *Scientific Research: Plant Science Center.* Retrieved October 26, 2009, from http://www.nybg.org/explore_and_learn/scientific_research.php

(n.d.). *Sustainability and Climate Change Program: What the Garden is Doing.* Retrieved October 26, 2009, from http://www.nybg.org/sustainability/index.php

(n.d.). *Tree Tanglefoot Pest Barrier*. Retrieved October 26, 2009, from http://www.tanglefoot.com/products/barrier.htm