NATIVE AND NONNATIVE PLANTS IN FOREST INTERIOR VERSUS EDGE CANOPY GAPS IN WEST CHESTER, PENNSYLVANIA

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ABSTRACT: This research examines the composition of plants regenerating in the forest understory in gaps in the tree canopy in the Gordon Natural Area for Environmental Studies (GNA) at West Chester University in Pennsylvania. In this study, canopy gaps created by disturbances such as wind throw or senescence were identified in the GNA to compare the numbers of native and nonnative plant species found in them. The gaps were classified as located in the interior or mature forest versus the forest edge for comparison. The objective of the research was to evaluate the pattern of native and nonnative plant establishment in canopy gaps to inform forest restoration efforts in the GNA. Along the transect, plant species presence was recorded at 0.2 meter increments across the longest and shortest distances of the gap. A Mann Whitney U test was conducted to evaluate differences in the number of native and nonnative species in the gaps. For native species the U-value was not significant at $p \leq 0.05$ while for nonnative species the results were significant. The results suggest that native plants are found at similar frequencies in all canopy gaps, but that nonnative plants are found at higher frequencies in the gaps near the forest edge, and that this is where nonnative plant invasions occur. The species with higher frequency of observations were *Microstegium vimineum* (Japanese stiltgrass), *Rubus phoenicolasius* (wineberry), *Lonicera japonica* (Japanese honeysuckle), *Celastrus orbiculata* (oriental bittersweet), and *Lindera benzoin* (spicebush).

Keywords: *forest canopy gaps, native species, nonnative species, Gordon Natural Area, southeastern Pennsylvania*

INTRODUCTION

For forest remnants in suburban areas such as where the Robert B. Gordon Natural Area (GNA) is located, understanding the processes that impact native plant regeneration is important for preserving and promoting biodiversity. Research has shown that canopy gaps contribute to maintenance of species diversity by providing opportunities for regeneration to occur in the forest (Brokaw and Busing 2000; Gravel et al. 2010). A canopy gap occurs in the forest when a tree falls and opens up the forest floor to light (Muth and Bazzaz 2002; Dupuy and Chazdon 2008). The gap is then colonized by new growth (Fajardo and de Graaf 2004). The objective of this research is to compare the composition of understory native versus nonnative vegetation in the canopy gaps of the GNA based on their location in the interior of the forest versus the edge or in successional habitat.

Nonnative plant species invasions are important drivers of biodiversity loss worldwide (Vargas et al. 2013) that threaten the native forest ecosystems in the U.S. (Burnham and Lee 2010). In the eastern part of the United States, nonnative plant species have invaded and altered ecosystem structures in mature/interior forests (Johnson et al. 2006; Webster et al. 2006). For nonnative plant species there is extensive evidence showing that disturbances in forests enhance their ability to invade native ecosystems (Gorchov et al. 2011). An example of such disturbances are the natural and anthropogenic disturbances that create canopy gaps (Vargas et al. 2013). In some gaps, nonnative species establish and naturalize easily and outcompete native species for resources (Denslow 2003).

According to Vargas et al. (2013), newer gaps had more native species than older ones. This also happens in different types of forests (Webster et al. 2006; Burnham and Lee 2010; Gorchov et al. 2011; Vargas et al. 2011). Burnham and Lee (2010) conducted a study that compared the abundance of nonnative species in two different types of forests. They showed that nonnative species thrive in forests that had more disturbances, as the Gorchov et al. (2011) study showed. Vargas et al. (2013) determined that although species diversity was similar in two different types of forests, gaps that had more disturbances had more nonnative species. Once a nonnative species is established in an area, they can influence species composition, site conditions, canopy gap creation frequency and attributes, and disturbance regimes (Vilá et al. 2011). Removing nonnative species and restoring forests in the area can be challenging, depending on the species (Tassin et al. 2006). Regardless of the type of nonnative species, some gaps facilitate the establishment of them over native species (Arellano 2011).

In edge forests where there is increased availability of light, the magnitude and abundance of nonnative species is higher (Muth and Bazzaz 2002). Native species start reducing in numbers as the gaps become more invaded. Nonnative species alter the diversity of native plant species significantly (Vargas et al. 2013). This has been documented in larger gaps – more than 150 m^2 – and those that have been invaded before. Older gaps have also been shown to have more abundance of nonnative species (Fajardo and de Graaf 2004).

The research presented here evaluates the composition of native and nonnative plant species in the canopy gaps of the GNA. It is hypothesized that there would be a greater frequency of native plant species in gaps found in the interior of the forest, and that there would be a greater frequency of nonnative plant species in the gaps found on the edge of the forest. The findings will inform management decisions for the GNA.

STUDY AREA

The GNA is located in the southern part of West Chester University in Pennsylvania (Figure 1), named after Professor Gordon for his 25 years of service (D'Angelo 2009; Hertel and Turner 2009). The GNA was designated as a preserve by the Board of Trustees of West Chester University in 1971 (D'Angelo 2009). In 1973 the area was dedicated for education and research by the university (Hertel and Turner 2009). West Chester University students, staff and faculty work to improve and maintain the condition of the multiple ecosystems of the GNA, by promoting native plants and discouraging nonnative plants (D'Angelo 2009; Stern el al. 2013). The mission of the GNA is to preserve a natural area and serve as a laboratory for environmental studies. It is also used for teaching and research in numerous disciplines (D'Angelo 2009).

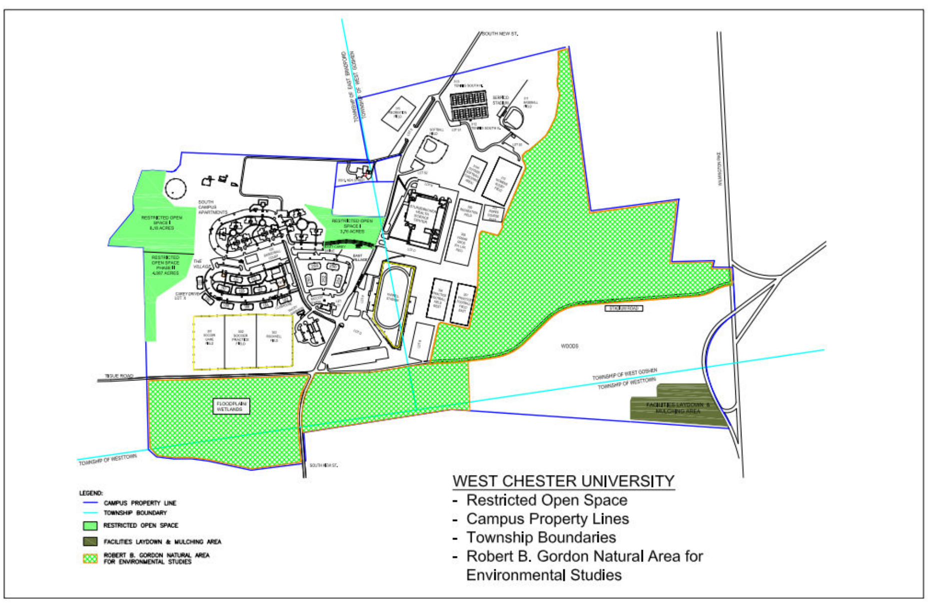

Figure 1. Map of the Gordon Natural Area. Source: West Chester University 2015.

In 2014, the Pennsylvania Department of Conservation of Natural Resources (DCNR) designated the GNA as a Wild Plant Sanctuary. The Wild Plant Sanctuary Program was established in 1982 through the Wild Resource Conservation Act to promote the establishment of native plant sanctuaries on private and municipal lands (Department of Conservation and Natural Resources 2014). The DCNR accepted the GNA into the program because of the commitment and efforts of the administration, faculty, and staff to promote the conservation of native plants (Department of Conservation and Natural Resources 2014).

Identifying the distribution of nonnative species in the gaps at GNA will provide an understanding of the areas that need to be focused on for restoration efforts. Previous research and projects completed at the GNA have improved the population of native species. Understanding the current state of gaps in the area will provide relevant information to the conservation of native species that are being affected by nonnative species. Since gaps may facilitate the establishment of nonnative species, ongoing research will provide important data on the GNA's critical areas for management.

Disturbances at the GNA

The GNA is ideal for deer because of available food resources, no hunting, and a low number of predators (D'Angelo 2009). High densities of deer affect and alter the understory of the area by browsing. Deer are a threat to native plant species in the area as they prefer eating certain plants over others which are typically understory native plants (Pomerantz and Welch 1996; Arnold and Welch 1996). Deer feed extensively on small plants, shrubs and trees, as well as many herbaceous and low-growing plants such as white trillium, blue bead lily and numerous orchids (Department of Conservation and Natural Resources 2013). At the GNA, deer have consumed native oak seedlings to the point where they can no longer be found (Hertel et al. 2012). This damages the vegetation in the area allowing the nonnative vegetation to thrive (D'Angelo 2009). Other disturbances in the area include nonnative plants, nonnative earthworms, and trail bikers (Hertel and Turner 2009; Hertel et al. 2012). These threats are causing a decline in biodiversity and extirpation of native plants in the GNA (Hertel et al. 2012). Historically the trees in the area were removed for agriculture, wood products and fuel. Recently, the development of residential and commercial areas has also played an important role in the loss of native vegetation. This allowed the entry and proliferation of nonnative species through the forest edges (Hertel el al. 2012).

METHODOLOGY

For this research all gaps that were not located along or across trails were considered and sampled. A total of 16 gaps were identified that met the criteria in the GNA in West Chester, Pennsylvania (see figure 2). Gaps were divided into two categories based on the part of the forest within which each was located: mature/interior or edge/successional forest. There were a total of nine mature/interior gaps and seven in the edge/successional forest. Gaps in the interior or mature forest were those that were located in the area dominated by established deciduous tree species and greater than 50 meters from the edge of the forest. This area was also less impacted by fallen logs and human impacts. Edge/successional gaps were those located in areas within 50 meters of the forest edge and in areas that are going through a transition of habitats. In each gap, a transect was laid across the longest and shortest distance across the opening. Data were collected at every 0.2 meters along the transect and all species recorded that were touching the transect. Only species in the understory were recorded from the soil up to 1 meter of height. Data collection occurred in October 2015. Species were classified as native and nonnative for each gap (see Huebner et al. 2005; Reshetiloff et al. 2002).

The frequency of native and nonnative species per meter was calculated in each gap. To calculate the frequency of observations of native species, the total number of observations in both the long and short transect of each gap was added. The total amount was divided by the total length of the long and short transects added together. The same process was repeated for the nonnative species. As the data were not normally distributed, the non-parametric Mann Whitney U test was chosen to evaluate whether there is a statistically significant difference between two locations according to the rank of variable values. Each of the 16 gaps were then ranked according to the frequency variables, and differences in ranks between the gaps in the interior versus gaps on the edge were evaluated using a one-tailed Mann Whitney U Test. When there are canopy gaps with the same frequency value, the rank positions of the ties are added together and then divided by the number of ties to determine the rank value which will be the same for all gaps that share the same frequency (Ebdon 1991).

RESULTS

The 16 gaps identified at the Gordon Natural Area and chosen for this study were classified as mature or interior, and edge or successional, depending on their location in the forest. Four of the total number of gaps were created by fallen trees already identified at GNA. The tree fall gaps were named after the number assigned to the trees by GNA managers. For example, Plot ID #11 was created by the tree fall of a white ash and swamp white oak. Plot IDs #12 and #18 were created by fallen red oak and red maple respectively, while plot ID #33 was created by two fallen red oaks. Plant species data collected along the transects yielded a total of 38 species (Tables 1 and 2), of which 24 were native and 14 were nonnative. Gaps in the edge/successional forest had the most observations of nonnative plant species.

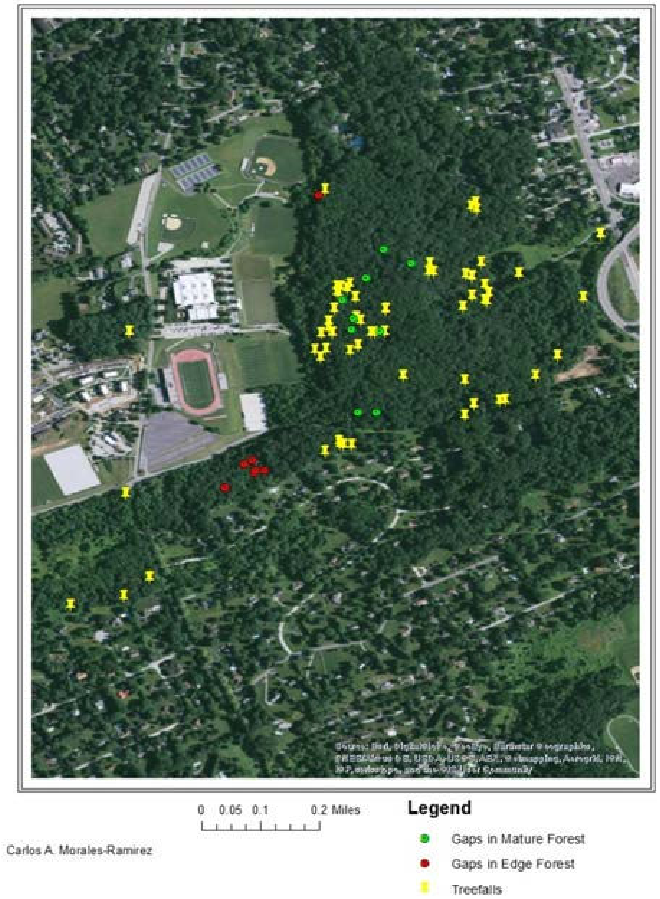

Figure 2. Canopy gaps in the Gordon Natural Area

Table 1. Nonnative plant species identified.

Abbreviation	Scientific Name	Common Name	Lifeform
Acpl	Ailanthus altissima	Tree of Haven	Tree
Alof	Alliaria petiolata	Garlic Mustard	Herb
Beth	Berberis thunbergii	Japanese Barberry	Shrub
Ceor	Celastrus orbiculata	Oriental Bittersweet	Vine
Eual	Euonymous alata	Burning bush	Shrub
Frve	Fragaria vesca	Woodland strawberry	Herb
Loja	Lonicera japonica	Japanese Honeysuckle	Vine
Loma	Lonicera sp.	Bush Honeysuckle	Shrub
Mivi	Microstegium vimineum	Japanese stiltgrass	Grass
Pocu	Polygonum cuspidatum	Japanese knotweed	Herb
Romu	Rosa Multiflora	Multiflora rose	Shrub
Ruph	Rubus phoenicolasius	Wineberry	Shrub
Elum	Elaeagnus umbellata	Autumn (Russian) Olive	Shrub

Table 2. Native plant species identified.

Abbreviation	Scientific Name	Common Name	Lifeform
Acru	Acer rubrum	Red maple	Tree
Asdi	Aster divaricatus	White Wood Aster	Herb
Coca	Collinsonia canadensis	Horse Balm	Herb
Cofl	Cornus florida	Flowering Dogwood	Tree
Fagr	Fagus grandifolia	American Beech	Tree
Fram	Fraxinus americana	White Ash	Tree
Gatr	Gallium triflorum	Sweet-scented Bedstraw	Herb
Libe	Lindera benzoin	Spicebush	Shrub
Litu	Liriodendron tulipifera	Tulip Poplar	Tree
Nysy	Nyssa sylvatica	Black Gum	Tree
Pobi	Polygonatum biflorum	Solomon's Seal	Herb
Qual	Quercus alba	White Oak	Tree
Rhra	Rhus radicans	Poison Ivy	Vine
Rub01	Rubus sp.	Blackberry species	Shrub
Saca	Sanguinaria canadensis	Bloodroot	Herb
Smro	Smilax rotundifolia	Roundleaf Greenbriar	Vine
Vaac/Vaan	Vaccinium angustifolium	Late Low Blueberry	Shrub
Viac	Viburnum acerifolium	Maple-leaved Viburnum	Shrub
Vica	Viola candensis	Canadian Violet	Herb
Vide	Viburnum dentatum	Arrowwood	Shrub
Vitus	Vitus sp.	Grape species	Vine
Euru	Eupatorium rugosum	White Snake Root	Herb
Carya	Carya sp.	Hickory	Tree
Bocy	Boehmeria cylindrica	False Nettle	Herb
Pham	Phytolacca americana	Pokeweed	Herb

Plot #1 was the gap in the mature/interior forest with the most observations with a total of 49. Of this total, there were more observations of native species, with 25 counts. The native species observed the most at each 0.2 increment, was the spicebush (*Lindera benzoin*). It was present nine times in the long transect and four time in the short one. The long transect in this gap was 10 meters and the short transect was 4.6 m. Other native species in the gap include: *Fagus grandifolia* (American beech), *Vaccinium angustifolium* (late low blueberry), *Viburnum acerifolium* (maple-leaved *viburnum*), *Carya* sp. (hickory), *Vitus* sp. (grape), and *Aster divaricatus* (white wood aster). The nonnative species present the most at each 0.2 meter increment, was *Celastrus orbiculata* (oriental bittersweet). This was present a total of 14 times in the long transect and five times in the short transect. The other nonnative species present in plot #1 was *Lonicera japonica* (Japanese honeysuckle). It was present three times in the long transect and two times in the short one.

The gap in the edge/successional forest with the most observations was Plot #13 with a total of 136. Nonnative species were present a total of 103 times. Japanese honeysuckle was the nonnative species present the most in this gap. It was present 33 times in the long transect and 15 times in the short transect. The long transect in this gap was 10.3 m and the short transect was 4.2 m. The native species present the most in this gap was spicebush. It was observed four times in the long transect and nine times in the short transect.

From the native species identified in all canopy gaps, spicebush was the one present the most with a total of 71 observations. The nonnative species present the most in all gaps was *Microstegium vimineum* (Japanese stiltgrass) with a total of 197 observations. Spicebush was the dominant native species in plots #1, 3 and 13 with a number of 13, 15 and 13 observations respectively. Japanese stiltgrass was the dominant nonnative species in Plots #7, 8 and 9 with a total of 39, 58 and 47 observations respectively. The other native species present the most in gaps were maple-leaved *Viburnum*, *Eupatorium rugosum* (white snake root), American beech, and *Gallium triflorum* (sweet-scented bedstraw). For nonnative species, the others present the most were: *Rubus phoenicolasius* (wineberry), Japanese honeysuckle, oriental bittersweet, and multiflora rose.

The frequency of each species count was calculated to determine the rank of both native (Table 3) and nonnative species (Table 4) in the mature/interior forest and the edge/successional forest. Once the ranks were determined for each of the 16 gaps, a Mann Whitney U test was performed to test for differences between the mature/interior and the edge/successional forest. The Mann Whitney calculated U-value for rank of native frequencies was 26.5 with the critical value of $p \leq 0.05$ at 15, and so the value was not significant for native species. For nonnative species the results were significant ($p \leq 0.05$) with the calculated U-value of 0 and the critical value of 15. Although there were fewer numbers of nonnative species, the total number of counts in the gaps was greater than native species. There was a wide variety of native species at the GNA. However, the observations were fewer than the nonnative species.

Table 3. Frequency of observations of native species per meter.

Plot ID	Type of forest	Frequency per meter	Rank
1	Mature/interior	1.6	6
2	Mature/interior	1.1	8
3	Mature/interior	2.3	3
4	Mature/interior	0.4	12.5
5	Mature/interior	3.2	1
6	Mature/interior	0.4	12.5
7	Edge/Successional	0.4	12.5
8	Edge/Successional	0.4	12.5
9	Edge/Successional	0.2	16
10	Edge/Successional	0.8	9
11	Mature/interior	1.5	7
12	Mature/interior	0.3	15
13	Edge/Successional	2.3	3
14	Edge/Successional	2.3	3
18	Edge/Successional	2.2	5
33	Mature/interior	0.6	10

Table 4. Frequency of observations of nonnative species per meter.

Plot ID	Type of forest	Frequency per meter	Rank
1	Mature/interior	1.7	9
2	Mature/interior	1.6	10
3	Mature/interior	0	15
4	Mature/interior	0	15
5	Mature/interior	0	15
6	Mature/interior	0.1	12.5
7	Edge/Successional	5.8	7
8	Edge/Successional	8.2	1
9	Edge/Successional	8.1	2
10	Edge/Successional	7.3	4
11	Mature/interior	7.1	5.5
12	Mature/interior	0.6	11
13	Edge/Successional	7.1	5.5
14	Edge/Successional	8	3
18	Edge/Successional	4.2	8
33	Mature/interior	0.1	12.5

CONCLUSION

The results of the research are consistent with previous findings in that edge/successional gaps provide opportunities for nonnative plants to establish in the forest edge. The largest counts of plant observations were found in the edge forest gaps and were dominated by observations of nonnative species. There were more mature/interior forest gaps than edge ones, but the gaps in the edge/successional forest had more observations than the ones in the mature/interior. In general, nonnative plant observations were double and sometimes triple the amount as compared to the observations of native plants. Although there was a larger number/variety of native species, there was a larger number of observations of nonnative species.

Gaps in the edge forest had a higher frequency of nonnative species than in the mature forest. Based on the results of the Mann Whitney U test, there is no statistically significant difference in the frequency of native species found in gaps. In general, the mature forest gaps are least disturbed as demonstrated by the lower frequency of nonnative plants. Nonnative species have significantly altered the abundance and diversity of native species in the area. This threatens native plant populations and reduces biodiversity. The results suggest that efforts to promote native and discourage nonnative plants in the GNA should focus on forest canopy gaps nearest the edge or in successional habitat areas.

This research was conducted with data collected during the fall season. Collecting data during each of the growing seasons would provide additional information to help understand how the distribution of native and nonnative species in forest canopy gaps changes throughout the year.

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