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Thesis Title **The impacts of Norway maple (*Acer platanoides*) on Northeastern urban forest community along an invasion severity gradient**

This thesis is submitted in partial fulfillment of the requirements for the degree of Masters of Science in Environmental Studies at Green Mountain College.

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The impacts of Norway Maple (*Acer platanoides*) on Northeastern urban forest community composition along an invasion severity gradient

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Abstract

Non-native invasive species pose a great threat to New York State ecosystems. The establishment of non-native invasive species into Northeastern ecosystems hinders conservation of the remaining greenspace across the state of New York. The Norway Maple (*Acer platanoides*) is a non-native invasive tree that alters habitats and ecological functioning such as changing native flora community compositions and forest structure, which negatively affects the native plant and animal species present in these ecosystems. This observational quantitative study compared three different severity levels of a Norway maple invaded urban forest located within the Anchor Diamond Park in the town of Ballston, Saratoga County in New York State. The primary objective of this study is to document the varying impacts associated with Norway maple tree invasions on Northeastern forest ecosystems based on the level of invasion severity. Invasion severity was quantified by the percent coverage of Norway Maple trees compared to other native and non-native invasive species within 9 sampling plots (3 plots in three severity sites- high, low-moderate, and absent). Native and non-native invasive species abundances was quantified, noted, and compared between the three severity sites. Site 1 has highest Norway Maple invasion severity where Norway Maple trees are dominate of the canopy layer and are high in value in average species richness and percent cover. Site 1 has lowest average species richness and percent cover for native plants and native plant species among all three forest strata layers. Site 1 has the lowest values for overall species richness for the canopy, shrub/sapling (except site 3), and forest floor stratification layers. The canopy layer at the high severity site was more closed reducing light reaching the understory layers of the forest stand resulting in less plant growth within the shrub/sapling and forest floor strata. Site 2 is the low-moderate Norway Maple invasion severity site, and there are not any Norway Maple trees found within the canopy strata layer but there

are saplings and seedlings present on and around the site. Site 2 has the highest overall species richness for all forest strata layers and has a moderately open canopy. Site 2 has the highest average species richness for both native and non-native invasive species within the shrub/sapling and forest floor strata layers. Within the low-moderate severity site the canopy has a greater openness, light levels were greater, and there was a higher average species richness in the understory strata all partially because there was not Norway Maple trees located in the canopy layer. Site 3 does not have Norway Maple present or any other non-native invasive species within any of the three forest strata layers including the canopy, shrub/sapling, and forest floor layers. Site 3 was used as a reference site and has the second highest average species richness and percent cover for native species within all the forest strata. The implications of this study guide specific management recommendations where Norway Maple has invaded at varying degrees of severity. Some management activities involving Norway Maple could include eradicating trees and saplings through basal bark, cutting, and/or herbicide treatments, manually removing seedlings, native plantings after eradication, samara collections, and continuous monitoring activities.

Table of Contents

List of Tables and Figures

Introduction

Norway Maple is a non-native invasive species that is currently invading Northeastern deciduous forests of North America. Norway Maple trees were introduced to North America during the mid-1700s from Europe for use as a street tree and have now spread and invaded many habitats among urban, suburban, and rural areas (Gomez-Aparicio & Canham, 2008). Norway Maple trees inhibit native flora growth, negatively affect regeneration cycles, and decrease the biodiversity and species richness of both open and closed forest ecosystems (Webb et al., 2001). This species is one of the most invasive tree species among Northeastern habitats and is strongly linked to inhibition of native tree species regeneration including the highly valued Sugar Maple, *Acer saccharum* (Paquette et al., 2012). There are strong concerns that Norway Maples may displace Sugar Maple and other native trees over time through forest succession processes and gap disturbance dynamics (Lapoint & Brisson, 2012).

Non-native invasive plant species possess specific traits that aid in their invasion success including phenotypic plasticity, rapid growth rates, disturbance tolerances, and abundant seed production (Reinhart, Greene, & Callaway, 2005). Norway Maple is shade tolerant, produces an abundant amount of heavy winged seeds (samaras) that are packed with large "nutrient reserves," and has the ability of withstanding a wide variety of environmental and anthropogenic generated stressors such as air pollution and nutrient poor soils (Webb & Kaunzinger, 1993; Gomez-Aparicio & Canham, 2008). This species can become established in both disturbed and closed forest ecosystems and has devastating impacts on the native biodiversity and species richness of understory microhabitats due to its dense canopy, large seed banks, and tolerance of both shade and sun light (Gomez-Aparicio & Canham, 2008). The leaves of Norway Maple trees have a longer leaf lifespan and a delayed senescence when compared to its native congener, Sugar Maple, which gives the invasive the ability to take advantage of resources during the fall season when other trees have discontinued their above-ground growth for the year (Lapoint & Brisson, 2012; Paquette et al., 2012). Norway Maple easily capitalizes on any canopy disturbance due to its rapid growth tendencies when exposed to light (Paquette et al., 2012). If an urban or closed forest experiences a large natural or anthropogenic generated canopy disturbance, the severity of a Norway Maple invasion can rapidly worsen (Wangen & Webster, 2006). Not only do Norway Maples successfully colonize shaded forest understories, waiting for their opportunity to rapidly take advantage of any opening in the canopy (Lapoint & Brisson, 2012), they also create large seed banks that will provide for future generations (Wangen & Webster, 2006).

Typically, a Norway Maple population consists of a large range of sizes including canopy and understory trees as well as a dense coverage of seedlings (Webb et al., 2001). The growth and recruitment rates of Norway Maple are higher than native species among both urban and closed forest ecosystems (Galbraith-Kent & Handel, 2011). Thus, the ecosystem alterations resulting from Norway Maple invasions have the potential of changing plant "competition hierarchies" among Northeastern urban forest plant communities (Gomez-Aparicio & Canham, 2008).

Non-native invasive species commonly enter, establish, and spread among disturbed areas and habitats (Bertin et al., 2005). Studies have proven that highways, streets, and railroads provide cleared pathways for non-native invasive species movements via seed dispersal away from developed areas where they may have been initially introduced (Wangen & Webster, 2006). The effects associated with non-native invasive species invasions on ecological processes among urban forests are "patchy" and are determined by the spatial distribution of native and non-native plant species among the habitat (Gomez-Aparicio & Canham, 2008). Many non-native invasive species alter native plant community compositions in numerous different ways (Reinhart, Greene, & Callaway, 2005).

Much research has shown that the lack of natural competitors and niche availability, anthropogenic generated disturbances, changes in resource availability, and the utilization of allelopathy chemical defenses can increase the susceptibility of native plant communities to invasion (Reinhart, Greene, & Callaway, 2005). One hypothesis proposed by Simberloff and Von Holle (1999) stated that positive interactions between non-native invasive species can lead to an "invasional meltdown" involving plant invaders hastening invasive success of other non-natives resulting in the continuation of native displacement and local disappearances (Reinhart, Greene, & Callaway, 2005). Within urban forests non-native invasive species alter the composition of plant communities resulting in ones consisting of higher abundances of exotics present and lacking amounts of native flora (Bertin et al., 2005). Non-native tree invaders have great influences and substantial impacts on native plant communities because of their large sizes (Bertin et al., 2005).

Norway Maple's appealing structure, tolerance of nutrient poor soils and pollution, production of a broad canopy, and freedom from natural competitors are reasons why it is viewed as an attractive street ornamental tree species (Bertin et al., 2005). Since Norway Maples have historically been used as city street ornamental trees, over time, they have invaded and become a major component of urban woodlands and forests located in the Northeast (Webb & Kaunzinger, 1993). Smaller sized nature preserves located within or around urbanized areas are especially susceptible to Norway Maple and other non-native invasive species invasions because of their close proximity to developed lands and frequent exposure to anthropogenic caused disturbances (Webb & Kaunzinger, 1993). Non-native invasive species are introduced to urban forests more often than areas less exposed to anthropogenic disturbances (Bertin et al., 2005). Urban forest understories invaded by Norway Maple have a lowered species richness and increased quantities of conspecific seedlings when compared to habitats that are not invaded by the invasive tree species (Reinhart et. al, 2005).

Norway Maple trees cause very large shifts in the native plant communities of forest understories, inhibit the recruitment, regeneration, and growth of native canopy dominants, and facilitate the recruitment of its own seedlings and saplings (Reinhart et. al, 2005). The ability of Norway Maple to inhibit native growth via direct competition and through shading effects while avoiding conspecific damage, strongly contributes to its invasion success (Galbraith-Kent & Handel, 2008). One study found that native plant diversity beneath a Norway Maple decreases and the quantity of conspecifics increases, as the size of the invasive tree increases with age (Reinhart et al., 2006). If Norway Maple's current blankets of seedlings and saplings among the understories of invaded Northeastern urban forests transform into the canopy dominating trees of the future, native plants will suffer substantial population losses and possible local extinctions (Webb & Kaunzinger, 1993). Present trends involving seedling and sapling growth has lead researchers to believe that in general Norway Maple trees are a "self-replacing" species because of their homogenizing effects on plant communities and large seed banks (Wyckoff & Webb, 1996).

Species invade a new community in three phases: "introduction, colonization, and naturalization" (Wangen & Webster, 2006). After the introduction of non-native invasive species to new ecological systems, many undergo a "lag phase" involving the slow growth and spread of invasive populations (Reinhart et. al, 2005). Tree invasions occur at a slower pace than those of non-native invasive shrub and herbaceous species (Bertin et al., 2005). Wangen and Webster (2006) suggest that woody invasive species have long generation times and spread their population ranges in waves that include numerous "lag phases". In many cases, after the initial introduction and lag phase are surpassed, some non-native invasive species populations seem to experience exponential growth patterns (Reinhart et. al, 2005). It is believed that Norway Maple populations experience the Allee effect (Reinhart et. al, 2005). Shade tolerant non-native invasive species such as Norway Maple experience longer establishment stages and undergo continuous lag periods during their population spreading invasion phase (Wangen & Webster, 2006). Norway Maple has long generation periods and undergoes prolonged invasion phases including colonization, establishment, and spread (Wangen & Webster, 2006).

Not much is known about the early stages of Norway Maple invasions into a new community and whether any modifications accelerate or inhibit further non-native invasive species invasions among forests (Gomez-Aparicio & Canham, 2008). Perennial woody non-native invasive plant species, such as the Norway Maple, establish patches and alter the structure and composition of native plant communities among Northeastern urban forest ecosystems (Wangen & Webster, 2006). Research on the different invasion stages of urban forests can reveal indicators of non-native invasive species threats that can occur, worsen, and spread over time if not caught during the earlier phases of invasion (Bertin et al., 2005). By studying several severities associated with the stages or phases of invasion rather than waiting until an entire forest patch has become invaded, land managers can better understand how this canopy species may transform ecosystem process that lead to its eventual domination of the overstory. It is very possible that the invasive threats involving Norway Maples will only increase in the future as more ecosystems undergo anthropogenic disturbances, such as fragmentation, excavating, pollution, urban expansion, and global warming. Thus, the Norway Maple tree is a major target for eradication efforts in New York State (Webb et al., 2001).

The main objective of this study is to document the different severity levels of a Norway Maple invasion and demonstrate the varying impacts these severity levels have on native plant communities (hereafter "severity sites" classified as none, low-moderate, and high). For example, if a forest patch has low-moderate invasion severity that means the presence of Norway Maple impacts native plant communities including a decrease in species richness and native biodiversity and conditions are such that other non-native invasive species are likely to dominate the understory. Very high severity of invasion would indicate suppressed growth of both native and non-native invasive species, and Norway Maple is the dominating species of the canopy layer lowering the overall species richness of understory strata. Therefore, I hypothesize that as the severity of a Norway Maple invasion increases within a Northeastern suburban forest, native plant biodiversity in terms of species richness and percent cover decreases facilitating additional non-native invasive species invasions. Another research objective of this study is to better understand the associated ecological impacts on plant community composition in each of the successional invasion phases of Norway Maple. Understanding the invasion biology of Norway Maple and its impacts at different levels of invasion severities will inform land management decisions regarding the most effective removal strategies to be used at each phase of Norway Maple invasions within Northeastern urban and closed forest ecosystems.

Methods

Data collection focused on first, characterizing different invasion severity stages within the Park. Then once sites had been identified as representing the various stages of Norway Maple invasion, I measured forest understory community composition and other environmental variables to assess the impacts Norway Maples have in different stages of invasion severity. All data collection occurred between June-August of 2017.

Research Site

The former Hawkwood Estate now designated as the Anchor-Diamond Park is 248 acres and in the Town of Ballston, Saratoga County, New York (Figure 1). The Hawkwood Estate was built in 1790, and was used for pasture, hayfield, and cropland development (Gaige, 2015). Prior land use was abandoned around 1960 as most forest stands are older than 50 years except for the Eastern Hemlock dominated stands. Deer hunting and recreation have been some of the only activities on the property since abandonment (Gaige, 2015). Prior to preservation for public use in 2016, the former Hawkwood Estate contained 2.2 miles of trails commonly used for recreation purposes including snowmobiling and other outdoor activities. The Estate’s previous owner, Frank W. Schidizick, Jr. requested in his will that the park remain forever wild and open for public recreational use (Gaige, 2015). The New York Department of Conservation, Saratoga Planning of Saratoga County, the Town of Ballston Commission, land managers, and other stakeholders have focused on trail maintenance and are now working to remove and/or control non-native invasive species invasions within the park. Anchor-Diamond Park is within the wildlife management unit 5R of New York State, and total deer per meter squared is 4.3 for this area (Department of Environmental Conservation, 2016).

The Anchor-Diamond Park is underlain by Canajoharie Shale which is a black shale of the Ordovician age (Gaige, 2015). Elevations throughout the park range from 360 to 550 feet and slopes are gentle (mainly flat). Approximately 35% of park property consists of New York State Department of Environmental Conservation (NYS DEC) and the Federal United States Army Corps of Engineers (USACE) protected wetlands (Gaige, 2015). There are two tributary streams that exist within the park which are located at the northwest and southwest corners of the property and both run into a central stream. The entire watershed of the Park drains into the Ballston Lake (Gaige, 2015). The wetlands located in the park are all swamps and swampy woods in addition to the stream and its floodplains (Gaige, 2015). Habitat types that currently exist at Anchor-Diamond Park include Mature Coniferous Forest, Mature Deciduous Forest, Sugar Maple Plantation, Old-Field White Pine Woods, Hemlock-Hardwood forest, Successional Northern Hardwood Deciduous Woods, Wet Woods, and a large wetland in the Southwest section of the preserve (Gaige, 2015).

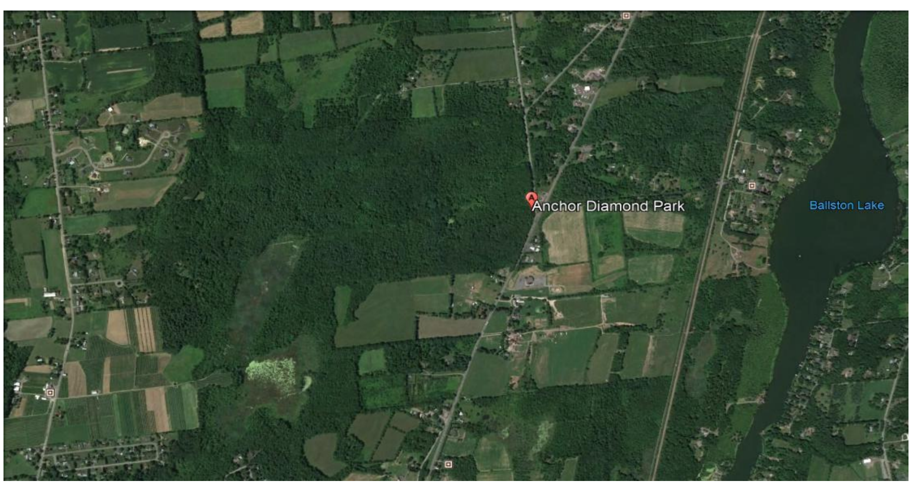

Figure 1. Anchor-Diamond Park located in the Town of Ballston is shown here in relation to current land use. The Park is surrounded by patches of agriculture and commercial and residential development (Google Earth, 2017).

Norway Maple has become a forest invader at this suburban park and managers are interested in controlling its invasion. Different areas within this park have differing invasion severities of Norway Maple trees. I sampled 3 sites within the Park to characterize the invasion severity and determine the impacts Norway Maple has on forest communities at various stages of invasion.

Study Site Invasion Severity Determinants

I determined the Norway Maple invasion severity by measuring the percent cover and presence/absence of Norway Maples within three forest strata: the canopy layer (vegetation >457 cm in height), the shrub/sapling layer (between 122-457 cm in height), and the forest floor layer (<122 cm in height) within 3 10m^2 sampling plots placed along a 50m ladder transect within 3 sites across the Park (total of 9 study plots) using a nested quadrant method to sub-sample each strata (Stohlgren et al., 1995, Figure 2). Each plot was placed 10m apart on alternating sides along each transect. I recorded the size in diameter at breast height (DBH) of Norway Maple trees and their age by extracting cores with an increment borer from trees in all sites and in all three strata. Tree core samples were stored in a refrigerator, dried at 60°C for a week, and sanded to expose rings. I estimated age using a dissecting microscope.

Other factors considered for Norway Maple invasion severity at all three sites include: past and present land use (Figure 3) and surrounding area land use (Figure 1) which was determined by utilizing an ecological report on the suburban park (Gaige, 2015) and Google Earth imaging and maps.

Assessment of Understory Impacts

To examine the effects of Norway Maple on understory characteristics in each site of varying invasion severity, I measured understory vegetation community composition and diversity, recorded soil temperature, % leaf litter cover and depth. Additionally, I recorded percent canopy openness using a spherical concave forest densitometer (Model C) and a light meter (EXTECH model 401025).

Along the transects within the $10m^2$ plots established within each invasion severity site as described above, I nested a $5m^2$ quadrant to measure percent cover shrub/sapling/climbing vines. Within those subplots, I nested a $2m^2$ quadrant to measure herbaceous plant/creeping vine cover (Figure 2, Stohlgren et al., 1995). I characterized the dominant community composition recording densities, percent cover, and species richness within each plot in all 3 sites. Species recorded were placed into one of three vegetation categories: Norway Maple, native, and non-native invasive plant species. I measured Norway Maples and other tree and shrub/sapling species using relative density estimates: # trees in each category (i.e. Norway Maple, native, and non-native invasive)/# of total trees * 100, and percent cover classes using the Braun-Blanquet scale (Wilson, 2010) estimates for smaller individuals and seedlings (See Appendix Figure A). In sites where Norway Maple was absent, that category was removed.

Environmental Variables

Soil temperature was recorded using a soil thermometer that was placed in the middle of each $10m^2$ plot and averaged per transect at all three sites. Soil types at each site were determined based on soil maps from a USDA web soil survey reference (http://websoilsurvey.nrcs.usda.gov). I recorded litter species composition and form (leaf, needle, etc.). Litter depth, measured in the center of each $10m^2$ in all sites, was determined using a ruler and measuring from the ground surface to the top of the litter layer and averaged per transect at all three sites. The terrain which included the elevation at each of the three sites was characterized according to Gaige (2015) and using a handheld GPS unit (Garmin etrex 20x). Canopy openness at each of the three invasion severity sites was determined using a spherical concave forest densitometer Model-C. To measure canopy openness four recordings were taken facing each cardinal direction (N, S, E, and W) and averaged to estimate overall canopy openness for each $10m^2$ plot. Plot averages were then used to determine an average overall canopy openness for each site. Light reaching the understory was also measured using a light meter (EXTECH Instruments, model 401025) by taking 5 lux recordings, one at each of the four corners and the center of the 10 m^2 plot and averaged for each plot within each site. This was done for all three plots at all sites, and averaged to estimate overall light penetration within each site. I recorded soil disturbance evidence based on a presence/absence scale in each of the plots within each invasion severity site.

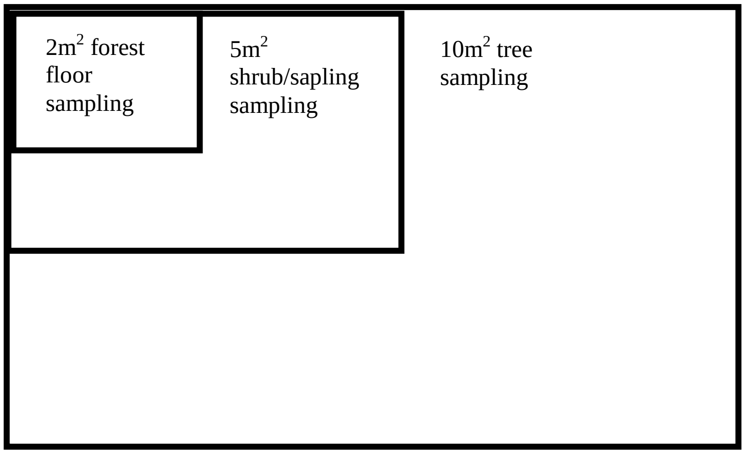

Figure 2. Nested quadrant plot method (Stohlgren et al., 1995).

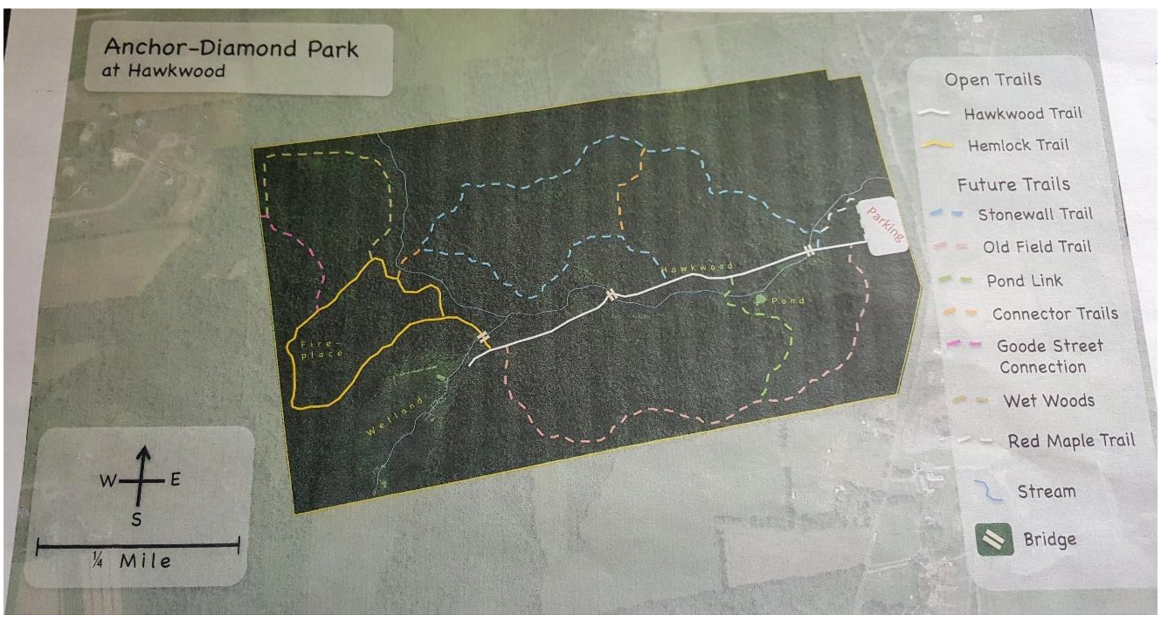

Figure 3. This is an image of a map with the current trail system established in 2015 at the Anchor-Diamond Park which is open to the public for use. This image displays some of the current land use at the park. This newly established trail system can contribute to the current and future spread of Norway Maple and other non-native invasive species within the Anchor-Diamond Park.

Results

Norway Maple has invaded the Anchor-Diamond Park with varying severity. First I describe the characteristics of each severity level. Second, I describe how the results from this study show that

Norway Maple is having a significant impact on the community composition in severely invaded and moderately invaded sites when compared to a reference site where it is absent.

Invasion Severity Characterization

Research site 1 (hereafter, site 1) with a high Norway Maple invasion severity is a mid-successional hardwood forest with a canopy layer dominated by Sugar (*Acer saccharum*) and Norway Maple (*Acer platanoides*) trees. Other trees species that are found on and around site 1 includes Red Maple (*Acer rubrum*), Ash (*Fraxinus spp.*), Black Cherry (*Prunus serotina*), and Black Locust (*Robinia pseudoacacia*). Virginia Creeper (*Parthenocissus quinquefolia*) dominates and Intermediate Wood Fern (*Dryopteris intermedia*) is less frequently found on the forest floor. Site 1 has the highest percent cover of Norway Maple in the overstory layer (Figure 4a and 4b, Figure 5a) but lacks well developed mid-canopy and forest floor strata. Cover of native species saplings was 67%, but shrub and forest floor growth are sparse (Figure 4a and b, Figure 5b and c). Norway Maple and Sugar Maple seedlings are found among the forest floor vegetation along with other non-native invasive species (Table 1). Norway Maple's dominance of the overstory influences environmental characteristics at site 1 (Figure 5a). Species richness, soil temperature, canopy openness, and light levels in site 1 are drastically lower than in site 2 (Figure 6, Table 2). Site 1 is located in the northeast section of Anchor-Diamond and was entirely cleared during the agricultural era through 1960.

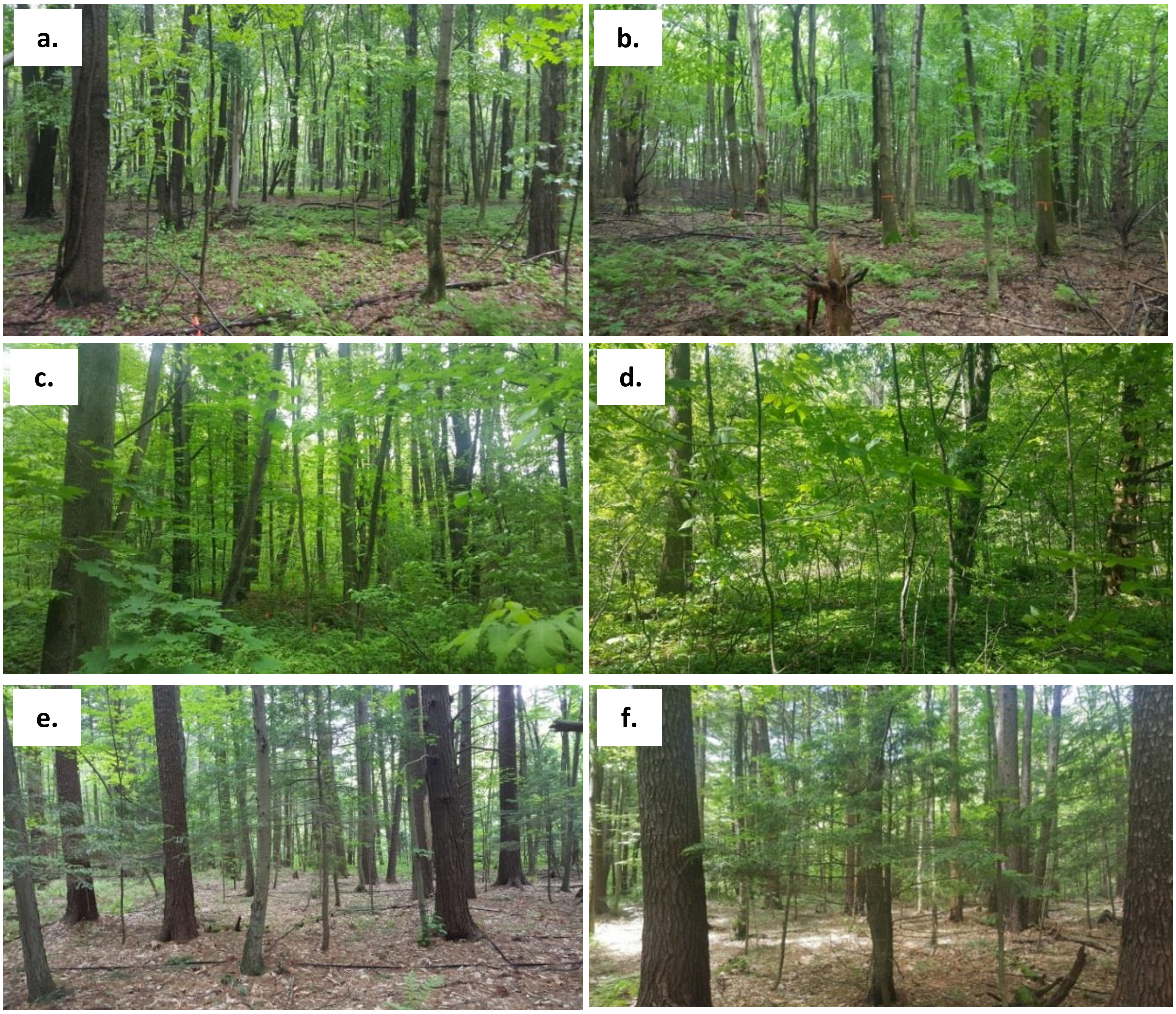

Figure 4. Photos a & b show lack of a developed understory at site 1. Photos c & d show dense understory growth in site 2. Photos e & f are of the understory growth at site 3 where Norway Maple is absent and the dominating tree species at this site are coniferous (Eastern Hemlock and Eastern White Pine).

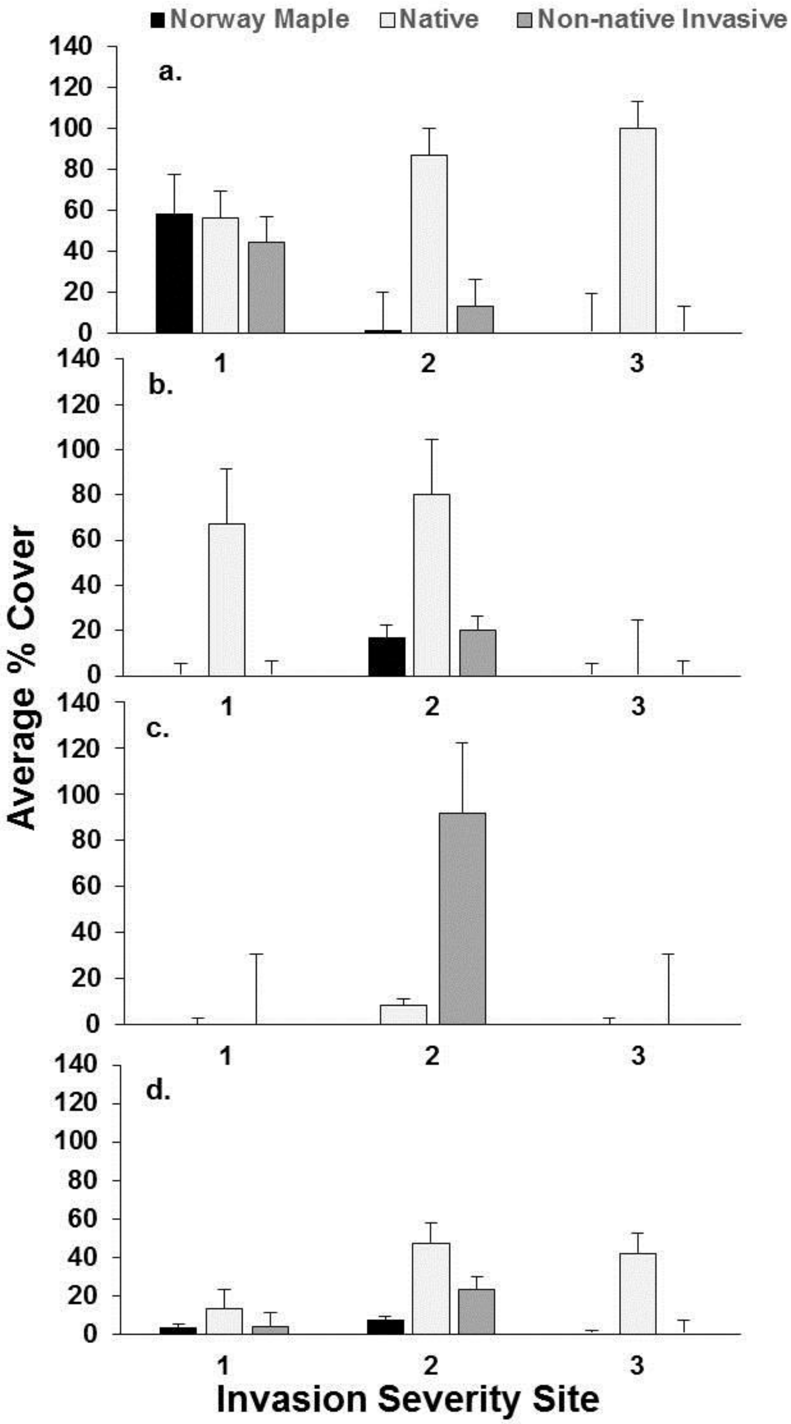

Figure 5. Average percent cover of Norway Maples, native species, and total non-native invasive species (including Norway Maples) in the a. overstory, b. sapling strata, c. shrub strata, and d. forest floor strata in invasion severity sites 1 (high), 2 (low-moderate), 3 (reference). Error bars are +/-1 standard error.

Table 1. Non-native invasive species found in or near study plots within each invasion severity site.

Site 1		Site 2	
Common name	Scientific name	Common name	Scientific name
Glossy buckthorn	*Rhamnus frangula*	European buckthorn	*Rhamnus*
Japanese barberry	*Berberis thunbergii*	Japanese barberry	*Berberis thunbergii*
Garlic mustard	*Alliaria petiolata*	Garlic Mustard	*Alliaria petiolata*
Black locust	*Robinia pseudoacacia*	Bush honeysuckles	*Lonicera spp.*
		Multiflora rose	*Rosa multiflora*

Table 2. Soil type, composition, temperature, leaf litter depth, canopy openness, and light readings for sites 1-3.

Variables	**Soil Type**	**Soil Composition**	**Elevation Range (ft.)**	**Average Soil Temperature** (°C)	**Litter Depth** (cm)	**Average Canopy Openness** (%)	**Average light** (lux)
Site 1: Severe	Broadalbin-Manlius-Nassau, undulating	deep, moderately drained, silt loam	440-510	3	4	13 (SE)	977 (SE)
Site 2: Low-Moderate	Mosherville-Hornell, undulating	deep, poorly drained, silt loam	397-438	14	3	29 (SE)	19765 (SE)
Site 3: Reference	Charlton Loam	deep well drained, glacial till	392-433	12	3	30 (SE)	968 (SE)

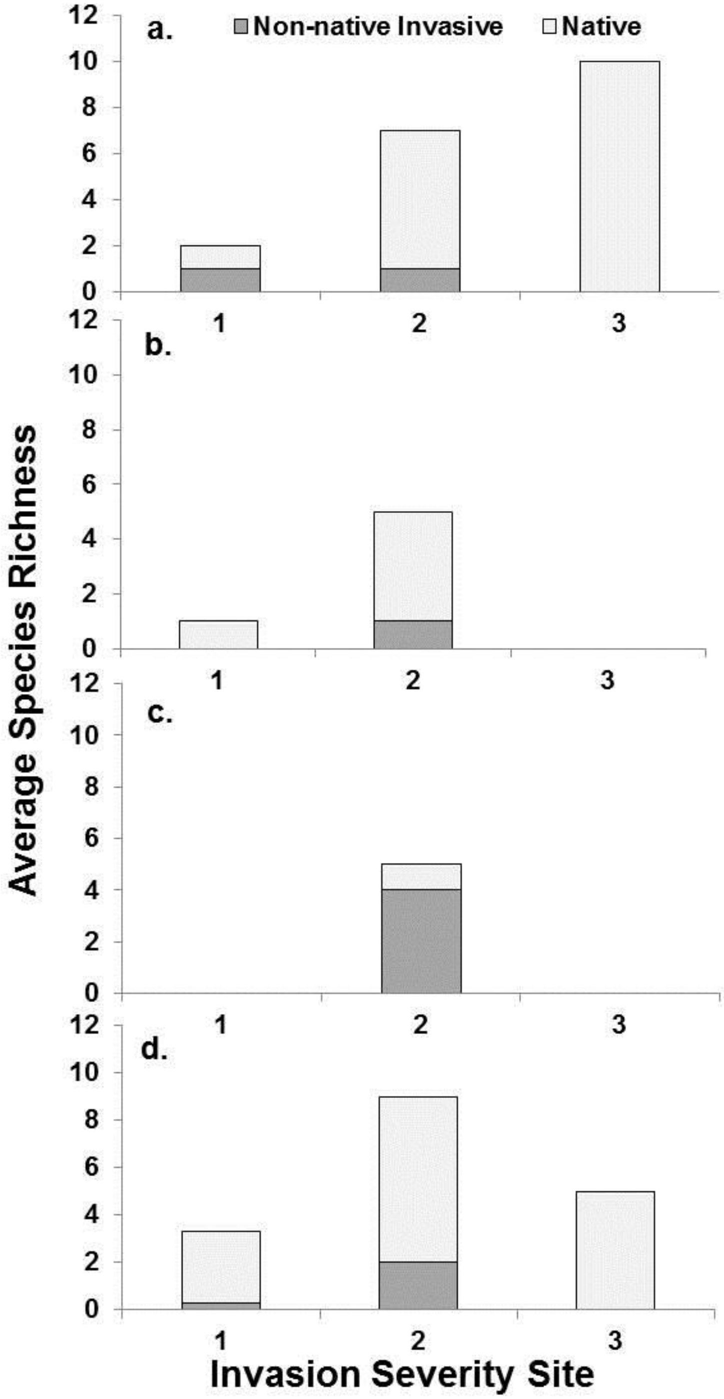

Figure 6. Average species richness of a. trees in the overstory strata, b. saplings in the mid-canopy strata, c. shrubs in the understory strata, and d. the forest floor strata at the high (site 1), low-moderate (site 2), and reference site (site 3).

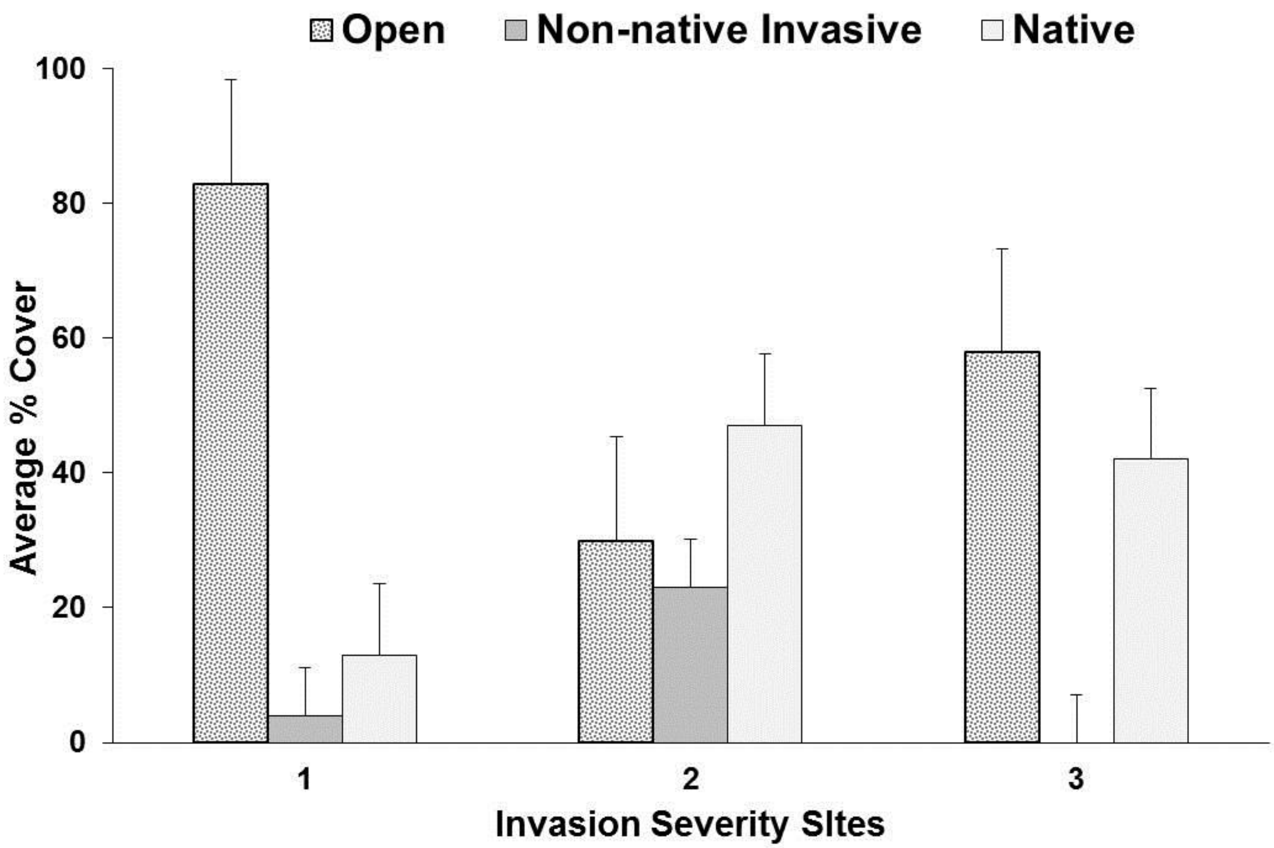

Figure 7. The average % cover of open patches in forest floor compared to % cover of native and non-native, invasive forest floor vegetation (including Norway Maple seedlings) at site 1 (high severity), site 2 (low-moderate severity), and site 3 (reference).

Research site 2 (hereafter, site 2) has a low-moderate Norway Maple invasion severity and is an open, early-successional forest with a canopy composition of various native tree species including American Beech (*Fagus grandifolia*), Eastern White Pine (*Pinus strobus*), Shagbark Hickory (*Carya ovata*), Sugar Maple (*Acer saccharum*), Black Cherry (*Prunus serotine*), Ash (*Fraxinus spp.*), Alder (*Alnus spp.)*, and Eastern Cottonwood (*Populus deltoids*), Elm (*Ulmus spp.*), European Buckthorn (*Rhamnus cathartica*), several other non-native invasive shrubs, and Norway Maple are also found in both canopy and understory layers (Table 1). The sub-canopy and shrub layer are dominated by European Buckthorn and Bush Honeysuckles *(Lonicera spp.)*. The forest floor strata layer is dominated by Sensitive Fern (*Onoclea sensibilis*), and drier areas are dominated by native intermediate wood fern

(*Dryopteris marginalis*), Virginia creeper (*Parthenocissus quinquefolia),* spotted jewelweed (*Impatiens capemsis*), hog peanut (*A. bracteate)*, and poison ivy (*Toxicodendron radicans*). Unlike site 1, the understory in site 2 is well developed including higher average percent cover and species richness in the mid-canopy and forest floor strata (Figure 4c and d, Figure 5). More light reaches the sub-canopy and understory layers than in site 1 even though canopy openness is similar to that in site 3, the reference site described below (Table 2). High cover of both non-native invasive (>20%) and native species (>40%) are found in the understory layer of site 2 (Figure 5c), and the highest non-native species richness is found in site 2, especially within the mid-canopy and forest floor strata (Table 2, Figure 6b and c). Site 2 is in the wet woods and early successional forest habit areas located in the Northeast section of the Park. Site 2 is located less than .25 miles up the blue trail to the right. Wetness is quite variable across site 2. The locations of plots 1 and 3 tended to be drier while plot 2 is damp after rain showers and contains a temporary creek.

I designated a reference site (hereafter site 3) that is absent of Norway Maple trees in all forest strata (Figure 4 e and f) within an Eastern Hemlock (*Tsuga canadensis*) and Eastern White Pine (*Pinus strobus*) dominated stand located in the western third of Anchor-Diamond Park (Gaige, 2015). This area was never cleared during the agricultural period and contains trees (including Red Maple) which are over 200 years old (Gaige, 2015). Canopy and subcanopy deciduous tree species found in site 3 include Red Maple (*Acer rubra),* American Beech (*Fagus grandifolia*), Ash (*Fraxinus spp.*), and Yellow Birch (*Betula alleghaniensis*). Site 3 is a closed forest habitat with an underdeveloped and/or absent shrub/sapling understory layer (Figure 5b). Canopy openness is limited resulting in sparse growth among the subcanopy and forest floor layers (Table 2, Figure 5b). Some of the lower and wetter areas have a more open canopy which allows for some forest floor vegetation (Figure 5c). Forest floor plant growth varies throughout the site and is dominated by Partridge Berry (*Mitchella repens*), Ash

(*Fraxinus spp.*) seedlings, and wood ferns (*Dryopteris spp.*) (Figure 4e and f). There is not any non-native, invasive flora species found within site 3 (Figure 6).

Impacts of Norway Maple on Forest Strata

Norway Maples most severely impact the shrub and forest floor strata in site 1 (Figure 5c, d; Figure 6c, d). A majority of the forest floor in site 1 contains open patches lacking vegetation of any kind (Figure 7). At site 1 there are larger and older Norway Maple trees than at site 2 indicating this species has a greater impact on plant communities in the understory strata at the high severity site (Figure 8). The relative absence of Norway Maples from the canopy in site 2 also affected percent cover and species richness within all forest layers of site 2 (Figure 5, 6). Site 1 has the lowest average percent cover of native forest floor plants (Figure 5d). Although, the forest floor plants that were present within plot areas sampled included native plant species as well as Norway Maple seedlings, average native species richness was greater than non-native species richness in this forest layer (Figure 6d). Site 2 has the highest average percent cover of native, non-native invasive, and Norway Maple forest floor plants than the other two invasion severity sites (Figure 5d). Site 2 has more native species present than non-native invasive species including Norway Maple (Figure 6d), and has more non-native invasive forest floor plants than Norway Maple seedlings which results in the average percent cover of non-native invasive forest floor plants being higher than Norway Maple for this invasion severity site (Figure 5d). Site 3 does not have any Norway Maple or other non-native invasive species present on site within any of the forest layers resulting in this invasion severity site having the lowest average percent cover of non-native invasive species and Norway Maple among all three invasion severity sites (Figure 5). Although site 3 served as the reference site, the percent cover of native species in the forest floor layer was about the same as that for site 2 and was greater than in site 1 (Figure 5d). Species richness in site 3 at the forest floor layer, however was lower than that at site 2 (Figure 6d).

Site 1 (where Norway and Sugar Maples codominate the canopy) has the greatest amount of open patches covering the forest floor compared to other sites (Figure 7). Although, the reference site, (site 3) also has more than 50% open patch cover, this is to be expected as it is a mid-late successional Eastern Hemlock dominated forest that has much more shade than site 2 (Table 1). The forest floor plant stratification layer at site 1 is underdeveloped and forest floor plant growth is sparse partly due to the lack of light availability resulting from the dense canopy layer that is dominated by Norway Maple trees. Site 3 has the second highest average percent cover of open patches. Site 3 has a dense canopy dominated by Eastern Hemlock trees and Eastern White Pine but there is still low to moderate forest floor plant growth within plot areas unlike invasion severity site 1 that has minimal forest floor plant growth. Site 2 has the lowest average percent cover of open patches which is partly because at this site the forest floor layer is well developed, has the highest forest floor plant species richness, and there is none to-little topsoil exposure. At site 2 there is much more average light availability than within some sites 1 and 3.

Table 3. Average DBH (cm), average age (yrs), and tree, sapling, and seedling abundance of Norway Maples in sites 1 & 2 (no NM present at site 3).

Variables	**Site 1** (n=20)	**Site 2** (n=5)
Average DBH (range)	110.7 (37-204)	12.4 (10-47)
Average Est. Age (range)	36.3 (11-60)	10.4 (6-19)
Mature trees	25 +	possibly 1
Immature trees	0	7
Saplings	4	12
Seedlings	>20	9

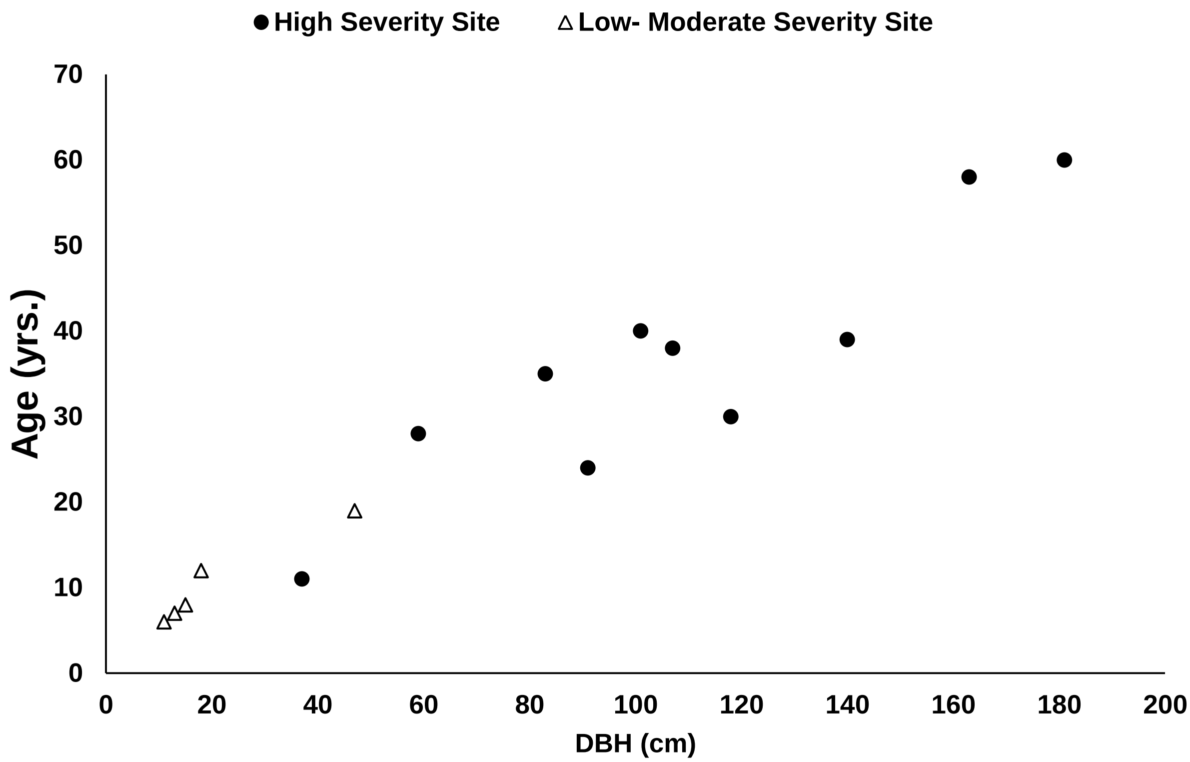

Figure 8 Relationship between the age and size of mature Norway Maple trees at the high invasion (site 1, n=10) and low-moderate invasion (site 2, n=5). Site 3 not shown as Norway Maple is absent.

Discussion

The main objective of this study was to document the different severity levels of a Norway Maple invasion and demonstrate the varying impacts these severity levels have on native plant communities such as species richness and percent cover. My study supports my hypothesis that as the severity of a Norway Maple invasion increases among a Northeastern suburban forest, native plant biodiversity in terms of species richness and percent cover decreases facilitating additional non-native invasive species invasions. Anchor-Diamond Park is a preserve that is made up of many different habitat types including wetlands, is the home to many animal and plant species, has important historical significance, and is open to the public for recreational use. Norway Maple trees have invaded areas of the park including site 1 and 2 and other parts of the preserve including the right and left forested buffer areas of the white main trail which runs from the east section of the part to the furthest west area.

There are other non-native invasive species that have also invaded areas of Anchor-Diamond park including European Buckthorn, Japanese Barberry, Garlic Mustard, Black Locust, Multiflora Rose, and Honeysuckle to name a few. Land managers of this park will need to address these non-native invasive dominant species to preserve native species richness. My study has shown that the effects of Norway Maple very depending on the level of invasion severity and on where it dominates in the forest strata.

Anchor-Diamond Park has similar issues influencing invasive species richness as studied in Lundgren et al. (2004) such as land development, soil texture (particle size), deer browsing, topography, elevation, current land use, and soil moisture (Lundgren et al., 2004). Novel ecosystems have developed in urban and suburban forests as of a result of land use change, flora and fauna species introductions, and natural and anthropogenic disturbances (Blood et al., 2016). In northeastern America, around 75% of non-native invasive plant species introductions are a result of horticulture plantings, such as the Norway Maple tree (Blood et al., 2016). Suburban forests are important fragments of reservoirs of valuable ecological functions and biodiversity (Johnson & Handel, 2016). Forest fragments within urban and suburban developed landscapes have a high "edge-to-interior" allowing for more risk of non-native invasive species introductions (Johnson & Handel, 2016). Urbanized areas are a strong driver of woody non-native invasive species abundances and richness at a landscape scale (Aronson et al., 2015). The increase in urbanization is expanding the rate of non-native invasive plant invasions and furthering the extent of effects they are having on native plant species (Huebner et al., 2012). Woody non-native invasive plant species with wind dispersed seeds, such as Norway Maple trees, have dispersal ranges of between 200 to 300 m (Huebner et al., 2012). Non-native invasive plants can spread freely through a fragmented landscape which has more road corridor connectivity, woodlots, abandoned farm fields, and forests, such as the Town of Ballston in New York where this study was conducted.

Norway Maple is one of the most desired and widely planted non-native invasive urban street trees in the northeast and is now being recognized as a serious threat to forest ecosystems (Wangen and Webster, 2006). In North America, Norway Maple is somewhat long lived (100-150 years) and can produce viable seed as young as 25 years (Wangen and Webster, 2006). Norway Maple is shade tolerant and is known to be an aggressive competitor against native plant species within forest understory layers. There are many studies that suggest that phenotypic plasticity is related to greater invasiveness among plant species, for example shade tolerant sun loving Norway Maple (Alpert et al., 2000). The high survival of Norway Maple in heavily shaded environments can be a result of this non-native invasive species tolerance to deep shade that is produced by itself (Reinhart et al., 2006). The shade tolerance of Norway Maple saplings and seedlings (Figure 5b and d) is partially due to their ability to change biomass allocation between roots and shoots in varying light conditions (Reinhart et al., 2006). Some studies also indicate that shade tolerant non-native invasive flora species more commonly invade protected forested areas that are located within or around developed areas (Martin et al., 2009). There are studies involving shade-tolerant non-native invasive species, such as Norway Maple, that show that they have strong impacts on diversity and structure within the understory forest stratification layers (Martin et al., 2009). My study confirmed as seen in the low species diversity and percent cover in the forest floor and shrub layers sampled at Anchor-Diamond Park (Figure 5, 6). The high seed production of non-native invasive Norway Maple trees replenishes the seedling bank at a greater rate than that of shade-tolerant native tree species (Martin et al., 2010). Non-native invasive Norway Maple has high growth rate, survivorship and fecundity resulting in this tree species ability to invade both disturbed and undisturbed forest ecosystems (Martin et al., 2010). Norway Maple has physiological mechanisms such as shade tolerance, and early leaf expansion and late leaf drop that is not seen in native Sugar Maple trees (Webb et al., 2000). The ability of non-native invasive Norway

Maple trees to impact species richness in all forest stratification layers as shown in my study raises issues involving preservation of ecosystem integrity (Webb et al, 2000).

In closed canopy low-light forest environments, shade tolerance commonly drives succession, both as interspecific differences in shade cast by mature trees and the shade tolerance of juveniles (Martin et al. 2009). Native (Sugar Maple) and non-native invasive (Norway Maple) tree species must be shade tolerant in order to survive multiple periods of suppression prior to canopy recruitment. The low light levels in forests that are heavily invaded by Norway Maple result in the rate of canopy recruitment (including by shade tolerant tree species) dependent on canopy gap dynamics where an absence of gap occurrence can result in a lag phase in invasions by shade tolerant non-native invasive tree species such as Norway Maple.

Canopy

At sites 1 and 2 Norway Maple has invaded forest strata layers. At site 1 Norway Maple dominates the canopy strata layer. Site 1 has the highest average percent cover for Norway Maple trees in the canopy layer, the highest average abundance of mature Norway Maple trees, and the lowest average tree species richness. Site 1 is located near the east border of the park where main roads and developed areas run along the forest edge. The Norway Maple trees within the canopy layer have broad dark colored leaves which result in a large and full canopy. There are not any canopy disturbances at site 1. It seems that Norway Maple has invaded Site 1 prior to reaching site 2 and it quite established within this forest stand. Invasion severity site 1 has the lowest average canopy openness out of all three sites and site 2 the highest. The high severity site has a closed canopy absent of gaps partially explaining why plant growth in the understory layers at this forest stand is sparse. Site 2 has the highest average canopy openness allowing more light to reach the understory layers of this forest stand resulting in more lush growth at this site compared to sites 1 and 3. In one study, a riparian area heavily invaded by Norway Maple trees had significantly more canopy cover and lower light levels within the understory than areas not heavily invaded (Reinhart et al., 2006). In eastern North America forests shade tolerant woody invaders that form monotypic stands, such as Norway Maple, decrease tree species diversity through inhibiting the recruitment and growth of native plant species (Wangen and Webster, 2006).

Unlike site 1, site 2 is located within the Northeast interior area of the park and does not have any mature Norway Maple trees located in the canopy layer. The canopy layer at site 2 is dominated by native deciduous trees that have smaller-sized lighter colored leaves. There is a 0 average percent cover of Norway Maple trees, as mentioned, within the canopy layer, and the average tree species richness is the highest out of all three sites. There are canopy gaps located at site 2 allowing much more light to reach the understory layers than at site 1. Site 3 was utilized as a reference site and does not have any Norway Maple within any of the forest strata layers or other any non-native invasive plant species present. Some studies have found that non-native invasive plant species invasions were mainly restricted to roadside buffer areas, open fields, and recent clear-cut areas and almost completely absent under mature or old growth forest stands and/or forest openings such as site 3 (Lundgren et al., 2004).

Shrub/Sapling

Site 1 has an underdeveloped shrub/sapling strata layer with no shrub species present and very few saplings present. Both Norway and Sugar Maple saplings are found at site 1, but there is little overall sapling growth. Site 1 and site 2 have been clear-cut prior to half a century ago unlike site 3 (Gaige, 2015). There is a very low average species richness for saplings at site 1 and an average percent cover of 0 for shrub species. This could possibly be due to the dark shade of by the mature Norway Maple trees in the canopy layer which do not allow much light to reach the understory layers resulting in suppressed and slowed growth of plants within these layers. Site 1 does have a moderately high average percent cover of native saplings (Figure 5b) and this is because out of the few saplings found in plot areas all of them were native Sugar Maple resulting in a higher average percent cover. Forest stands that are adjacent to site 1 are dominated by Sugar Maple trees and have much more growth in the understory layers including both the sapling/shrub and forest floor plant strata. Studies have shown that plant diversity within the understory layer below a Norway Maple tree declines as the size of the Norway Maple trees increased (Reinhart et al., 2006). Another reason why growth is sparse within the shrub/sapling layer including that of Norway Maple is because the absence of a soil disturbance. Both Sugar and Norway Maple are shade tolerant tree species that are able to grow in shaded environments, and the absence of growth within the understory layers could be the result of an absence of canopy and soil disturbances at this site. There is a higher abundance of Norway Maple seedlings at site 1 than there are saplings (Table 3). If there is a canopy disturbance at site 1 there is an opportunity for the Norway Maple seedlings to allocate energy into shoot growth resulting in rapid growth into saplings and later on mature trees.

At site 2 there is a high average percent cover of native sapling and non-native invasive shrub species. The shrub/sapling layer is well developed and has the highest average species richness including both native and non-native invasive species. The well-developed shrub/sapling understory layer could partially be due to the gaps present in the canopy and the dominance of deciduous native tree species in the canopy, which do not cast as much shade as site 1; in fact, site 1 has the highest amount of light reaching the understory layers (Table 2). There are few Norway Maple saplings found at site 2 and there are not any mature Norway Maple trees in the canopy or sub-canopy. There is a temporary stream and wetlands located at site 2 which could result in a richer load of nutrients in the soils, along with more light availability, allowing more plant growth within the understory layers. Site 2 has the highest average overall species richness (including both native and non-native invasive plant species) which leads to more competition for resources possibly inhibiting the rapid growth and spread of Norway Maple within this site. It is believed that more diverse plant communities utilize resources more fully which reduces availability to non-native invasive plants such as Norway Maple (Alpert et al., 2000). Site 2 has the highest abundance and percent cover of non-native invasive species out of all three sites, but also the highest percent cover and average species richness of native plant species. Since Norway Maple have the ability to spread and grow within shaded understories, a large pool of seedlings or seeds in the seedbank can accumulate in moderately undisturbed forests. These Norway Maple seedlings and saplings within forest understories are usually non-reproductive and can persist for over 30 years (Wangen and Webster, 2006).

Environmental conditions that benefit native plant species richness may also benefit non-native invasive plant species richness which can be observed at site 2 which has the highest native and non-native invasive plant species richness out of all three sites (Huebner et al., 2012). Site 3 also has a lower average light value much like site 1 partially due to the dark shade that the Eastern Hemlock trees provide which dominate the canopy. At site 3, there is an average percent cover of shrub species of 0% and there is no sapling growth within plot areas. Much like site 1, the shade that the canopy provides may result in the slow or suppressed growth of plant species in the shrub/sapling layer. There are also more acidic soils at site 3 due to the tree species that dominate the canopy layer including Eastern Hemlock and Pine.

Forest Floor

It is possible that there is a high average percent cover of open patches within the forest floor layer at site 1 because of the Norway Maple dominated canopy limiting light which can result in the suppression of both native and non-native invasive plant species growth. Site 2 has the lowest average percent cover of open patches within the forest floor plant layer possibly due to the diverse plant community among this layer and the higher light availability due to the more open canopy. Site 2 has the highest percent cover and average species richness for both native and non-native invasive plant species within the forest floor layer. Unlike sites 1 and 3, site 2 has a soil disturbance within plot area 2, a ephemeral creek bed, and soil moisture varies throughout the site, for example, there is wetland in-between plot 2 and 3. Canopy openness and light availability also vary throughout site 2 where plots 1 and 3 have a less open canopy and plot 2 has large canopy gaps with high light availability. The forest floor layer at site 2 is well-developed with an abundant amount of growth. Site 2 has the highest species richness and percent cover of native and non-native invasive species within the forest floor partially due to the higher availability of light, higher canopy openness, diverse plant community, present soil disturbance, varying habitat conditions, and absence of mature Norway Maple trees in the canopy layer.

Non-native Invasive Species Management for Anchor-Diamond Park

Many studies involving non-native invasive plant species, such as Norway Maple, show that they have strong impacts on native understory and structure (Martin et al. 2009). The slower rates (lag phases) of woody non-native invasive plant species invasions may explain why the severity and long-term impacts on forest ecosystems have been overlooked worldwide (Martin et. al, 2009). The longer establishment phases and multiple lag phases during the expansion phase associated with non-native invasive woody tree species invasions, such as Norway Maple, make it that shade tolerant non-native invasive woody plant species are of a great unnoticed (until it is too late) threats to forest ecosystems (Wangen and Webster, 2006). Spreading knowledge of non-native invasive invasion processes in urban landscapes is crucial because of the increasing rate of global urban development and the related risk in biotic invasions which can impact the health of ecosystems and urban residents (Chytry et al., 2016).

Due to limitations as far as reversing many disturbance types and non-native invasive species invasions, conservation efforts should focus on protecting areas that are not yet invaded (site 3) and reducing the impacts of currently non-native invasive plant invaded populations (sites 1 and 2) (Lundgren et al., 2004). The removal of Norway Maple trees in a Northeastern forest resulted in the higher levels of recruitment of native plant species (Reinhart et al., 2006). However, some successful eradications have had undesirable effects on the invaded ecosystems, such as the establishment or increase in other non-native invasive plant species populations once the target species has been removed (Zavaleta et al., 2016). This could particularly be the case if the mature Norway Maple trees located in the canopy forest stratification layer were eradicated. This would disturb both the canopy, leaving large gaps, and the soil which could result in Norway Maple saplings and seedlings being suppressed in the understory layer to allocate energy into shoot growth and can disturb the seed bank where more seedlings are allowed to form a carpet along the forest floor. The rapid eradication of a non-native invasive plant species without restoring native flora species can result in a new unwanted invasion and leave other species without shelter and/or resources (Zavaleta et al., 2016). When contemplating the eradication of non-native invasive species from an ecosystem, land managers can take into account the following considerations in order to reduce ecological risks: a.) trophic interactions among non-native invasive species and between native and non-native invasive species b.) the roles of the target non-native invasive species within the ecosystem c.) post eradication monitoring (Zavaleta et al., 2016). Non-native invasive species removal is a very important activity of the conservation and management of many forest ecosystem types (Zalaveta et al., 2016).

The process of reversing a Norway Maple invasion in forest ecosystems involves many steps including future tasks such as monitoring and further clipping events. The management of suburban forests invaded by Norway Maple should include the removal of trees, saplings, and seedlings every 2 to 3 years (Galbraith-Kent & Handel, 2008). An efficient eradication effort should remove all Norway trees, monitor seed banks, and clip any seedlings that emerge (Webb et al., 2001). After Norway Maples have been clipped, a follow up herbicide treatment should occur to ensure the absence of future resprouts (Galbraith-Kent & Handel, 2008). Periodic removal and clippings of Norway Maple saplings and understory trees will be needed to guarantee efficient removal of the invasive species from the forest ecosystem (Webb et al., 2001). To make sure that the removal of a non-native invasive species from an urban forest ecosystem does not facilitate the invasions of others, management sites must be small in size, and native species must be planted after eradication of the non-native invasive species (Webb et al., 2001). Future monitoring of non-native invasive species management sites must occur, and restoration efforts involving these areas should continue throughout the year on an annual basis.

Having knowledge of the intensity and duration of a non-native invasive plant species invasion (severity) within an area is important when trying to practice successful restorative activities such as eradication efforts. For example, Norway Maple can be fully eradicated at site 2 in a shorter span of time (than at site 1 which has many large mature trees in the canopy) than at site 1 because of the lower invasion severity including the less abundant number of trees, saplings, and seedlings. It is an important strategy to plant native species where Norway Maple trees have been removed in order to lessen the risk of worsening the invasion of facilitating a new one.

Identifying rapidly spreading non-native invasive species at an early stage (site 2) should be of high management priority because there is a lesser chance of controlling their spread after it has become a widespread issue (site 1 and along white trail) (Aikio et al., 2010). It is recommended that more focused and intensive surveying for woody non-native invasive species occur to gauge when they may start to increase in abundance and distribution (Aikio et al., 2010).

Prior to the removal of Norway Maples from sites 1 and 2 eradication assessments should occur as well as in other areas that are invaded by non-native invasive plants to tailor removal to avoid undesirable ecological effects. Within the Anchor-Diamond Park there should be pre-eradication assessments taken for each non-native invasive species that are found at severity sites 1 and 2 as well as other areas that are invaded throughout the preserve. A post eradication assessment should also be carried out involving the effects of removal of Norway Maple, on both the non-native invasive species of interest and the invaded ecosystem (Zavaleta et al., 2016).

The removal of non-native invasive plant species, such as Norway Maple trees within the canopy layer at site 1, can greatly reduce the habitat and resource available to fauna species if there are not any further restoration activities in place after eradication measures (Zavaleta et al., 2016). Non-native invasive plant species that have become dominant within an urban forest ecosystem can serve as ecosystem engineers affecting diversity and dynamics of the system. Land managers must decide whether eradication of the target species is ecologically dangerous to other flora and fauna species and the ecosystem as a whole (Zavaleta et al., 2016).

Manual removal of seedlings, saplings, or mature trees can stimulate re-growth of the target species and can also facilitate the establishment of other invasive species (Webb et al., 2001). Soils become disturbed once plants are uprooted which can worsen an invasion. If root stock is not completely removed from the soil, resprouting can occur (Webb et al., 2001). Although manual removal may benefit native species such as sugar maple, removal of seedlings must be continued until the seedbank is diminished and to prevent further establishment that increased soil disturbance and canopy openings may promote (Webb et al., 2001).

Non-native Invasive Species Management Recommendations for Sites 1-3

Site 1

Site 1 is severely invaded by Norway Maple and is need of management. Since there are many of large mature Norway Maple trees at site 1 (Table 3), eradication of this species all at once is not recommended. Clear cutting these species would cause a large disturbance to the forest stand and could negatively affect the plant and animal species that reside within it. Allowing much more light to reach the understory layers could facilitate more non-native invasive species invasions along with worsening the Norway Maple invasion at site 1. At site 1 gradual removal of Norway Maple trees is recommended through treatments such as basal bark herbicide treatments, cutting and treating the remaining stump, and/or through girdling. Along with the gradual removal of Norway Maple trees at site 1, seedlings can be pulled and replaced with native plant species, and saplings can be eradicated through cutting and stump herbicide treatments. The forested buffer areas along the main white trail that are also heavily invaded by Norway Maple can also go through this process of gradual removal. Throughout the process of fully eradicating Norway Maple at site 1 and other heavily invaded areas monitored for soil and gap disturbances should be ongoing. Other non-native invasive species found at site 1 such as Garlic Mustard and Japanese Barberry can be removed through pulling and digging up techniques (i.e. Japanese Barberry-removal of root system). There are Black Locust trees surrounding site 1 that should also be gradually removed through herbicide treatments or other eradication techniques. During the spring, summer, and fall continuous non-native invasive species surveying activities should be carried out at and around site 1 to monitor and map where non-native invasive species including Norway Maple are invading (further management needed) and where eradication efforts taken place (continuous monitoring for new invasions).

Site 2

Since site 2 does not have any Norway Maple trees in the canopy the young trees, saplings, and seedling that are found on site can be removed through a more rapid process than at site 1. At site 2 Norway Maple seedlings can be removed through pulling techniques and can be replaced with native plant species. Norway Maple saplings and young trees can be removed through cutting and stump herbicide treatments. These techniques should cause minimal if any soil disturbances. There is an abundant amount of European Buckthorn, Bush Honeysuckles, and Multiflora Rose at site 2 so gradual eradication efforts through cutting, herbicide treatments, and manual (digging up) removal of these species is recommended in conjunction with Norway Maple control efforts. Other non-native invasive species found at site 2 include Garlic Mustard and Japanese Barberry. Garlic Mustard and Japanese Barberry are not abundant at site 2 so rapid removal of these two non-native invasive species is recommended. Since there are large canopy gaps and much more light availability at site 2 than at site

1, managers must use eradication techniques such as native plantings and avoiding soil disturbances in order to not facilitate new invasions. Seasonal surveying and monitoring should occurring prior, during, and after non-native invasive species management efforts and activities.

Site 3

Site 3 does not have any non-native invasive species present. Unlike the habitats that exist at Anchor-Diamond Park, the forest stand at site 3 has not been clear-cut during the last century (Gaige, 2015) and is dominated by Eastern Hemlock trees. Although site 3 has not yet been invaded by any non-native invasive species it is surrounded by forest stands that are invaded by one or more of these species including Norway Maple which poses a threat to the Eastern Hemlock forest stand that is in this west area of the park. Current and future monitoring and surveying for non-native invasive species should occur at site 3 for early detection purposes and remove/manage any invasion that may occur while in its earlier stages before it reaches to the severity at site 1 (Norway Maple) and site 2 (Honeysuckle, European Buckthorn, and Multiflora Rose). There is a non-native invasive pest species, Hemlock Woolly adelgid (*Adelges tsuga*), that is a major threat to Eastern Hemlock. Hemlock Woolly adelgid (HWA) has been found within and counties surrounding Saratoga County where Anchor-Diamond Park is located. At site 3, surveying for HWA should occur throughout the year immediately and into the future especially during its two reproductive cycles in attempt to detect any invasion during its early stages which can be more easily removed than if found at a more severe invasion stage.

Conclusion

The main objective of this study was to document the different severity levels of a Norway Maple invasion and demonstrate the varying impacts these severity levels have on native plant communities such as species richness and percent cover.

Anchor-Diamond Park is a preserve with a wide array of habitat types, mammals, fish, birds, and amphibians. There are U.S. Army Corps of Engineers recognized wetlands and streams that empty into the Ballston Lake located at Anchor-Diamond Park giving this particular preserve important ecological value because of its many ecological functions. It is crucial to conserve the habitats within Anchor-Diamond Park and one way of doing this is to monitor for, remove, and slow/stop non-native invasive flora and fauna species invasions. Anchor-Diamond Park provides many habitats for a diverse community of plants and wildlife. Since Anchor-Diamond Park is located in such a diverse landscape matrix compromised of residential, commercial, and agricultural lands, non-native invasive species are a great threat. It is common for non-native invasive species to disperse and spread throughout fragmented landscapes via roads, automobiles, birds, water, and mammals. Anchor-Diamond Park is of significant importance because of its ecological value, historical significance, diverse ecological system with many habitat types, ecological functions, harbors wetlands that provide habitat (vernal pools) for amphibians, and its recreational purposes. Urban sprawl is a large issue occurring in New York State including the County of Saratoga. Anchor-Diamond Park is some of the dwindling greenspace that remains in the Town of Ballston and for this reason alone its ecological value should be protected and conserved. The non-native invasive species that are invading areas within the park are decreasing the ecological functioning and overall value of Anchor-Diamond in different ways. For example, the Norway Maple invasion at site 1 could possibly be one of the reasons why species richness in the canopy, shrub/sapling, and forest floor layers is of a lower value. When an species richness and diversity decrease within an ecological community, in many cases, so do the ecological functions if not replaced by a species that provides these needed functions. Anchor-Diamond Park is in need of non-native invasive species management at sites 1 and 2 and many other areas throughout the preserve. Continuous monitoring, surveying, and eradication efforts and activities involving non-native invasive species must be carried out at Anchor-Diamond preserve to conserve and protect the ecosystem functionality as a whole and its overall value to plants, wildlife, and humans.

Collaborative efforts between stakeholders and organizations such as IMapInvasives, Saratoga Planning, PRISMS, the Town of Ballston Committee, the New York State Department of Environmental Conservation, volunteers, and others should occur on a monthly basis to come up with the effective plans to manage the park for non-native invasive species and conserve its ecological functioning and values.

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Appendix

Site 1-3 Data Average Table (1)	Site 1	Site 2	Site 3	Standard Error
Average Number of Trees in Plots	3	24	10	6.173419726
Average # of NM Trees	2	0	0	0.666666667
Average # of Native Trees	1	13	10	3.605551275
Average # of NNIS Trees	2	3	0	0.881917104
Average # of Tree Species	2	7	5	1.452966315
Average # of NNIS Tree Species	1	1	0	0.333333333
Average # of Tree Species Native	1	6	10	2.603416559
Average % Cover of NM Trees	58%	1%	0%	0.191688405
Average % Cover of Native Trees	42%	90%	100%	0.179009621
Average % Cover of NNIS Trees	58%	9%	0%	0.18021592
Average % cover of native tree species	56%	87%	100%	0.130511813
Average % Cover of NNIS tree species	44%	13%	0%	0.130511813
Average # of Shrubs	0	33	0	11
Average # of NM Saplings	0	5	0	1.666666667
Average # of Native Tree Saplings	1	7	0	2.185812841
Average # of Native Shrubs	0	1	0	0.333333333
Average # of NNIS Shrubs	0	21	0	7
Average % Cover of NM Saplings	0%	16.50%	0%	0.055
Average % Cover of Native Saplings	67%	23%	0%	0.19655364
Average % Cover of Native Shrubs	0%	3%	0%	0.01
Average % Cover of NNIS Shrubs	0%	55%	0%	0.183333333
Average % Cover No Forest Floor Growth	83%	30%	58%	0.1530795
Average # of Forest Floor NNIS Species	1	3	0	0.906151815
Average # of Forest Floor Native Species	3	7	5	1.154700538
Average % Cover Native Forest Floor Growth	13%	47%	42%	0.105987421
Average % Cover of NM Seedlings	3%	7%	0%	0.020275875
Average % Cover of NNIS Forest Floor Growth	4%	23%	0%	0.070945989

Average # of shrubs species	0	4	0	1.333333333
Average # of shrub native species	0	1	0	0.333333333
Average # of shrub NNIS species	0	4	0	1.333333333
Average # of saplings species	1	5	0	1.527525232
Average # of sapling NNIS species	0	1	0	0.333333333
Average # of sapling native species	1	4	0	1.201850425
Average % cover of native shrub species	0%	8%	0%	0.026666667
Average % cover of NNIS shrub species	0%	92%	0%	0.306666667
Average % cover of native sapling species	67%	80%	0%	0.247857486
Average % cover of NNIS sapling species	0%	20%	0%	0.066666667
Average # of Overall herbaceous species	4	10	5	1.855921454
Average % Cover of NNIS Saplings	0%	16.50%	0%	0.055
Average number of NNIS tree saplings	0	5	0	1.666666667
Average % Cover of Forest Floor Growth NNIS Species	23%	37%	0%	0.107857931
Average % Cover of Forest Floor Growth Native Species	77%	63%	100%	0.107857931

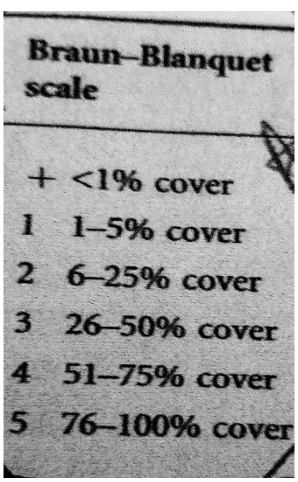
Table A. This table shows the data calculation averages for each category including: abundance, percent cover, and species richness for each forest stand strata including: canopy, shrub/sapling, and forest floor at each of the three severity sites.

Ranges (based of plots 1-3 raw data values)	Site 1	Site 2	Site 3
Total # of trees found in plots	3 to 4	12 to 36	6 to 15
Total # of NM trees found in plots	1 to 3	0 to 1	0
Total # of NNIS trees found in plots	1 to 3 (NM only)	0 to 5	0
Total # of NNIS tree species found in plots	1	0 to 2	0
Total # of overall tree species found in plots	2 to 3	5 to 8	3 to 7
Total # of native tree species found in plots	1 to 2	5 to 6	3 to 7
Total # of shrubs found in plots	0	26 to 47	0
Total # of Norway Maple saplings found in plots	0	4 to 7	0
Total # native tree saplings found in plots	0 to 1	6 to 8	0
Total # of NNIS tree saplings found in plots	0	4 to 7	0
Total # of sapling species found in plots	1	4 to 5	0
Total # of shrub species found in plots	0	3	0
Total # of sapling species native	1	4	0
Total # sapling species NNIS	0	1	0
Total # of native shrubs in plots	0	0 to 2	0
Total # of NNIS shrubs in plots	0	12 to 37	0
Total # of forest floor plant species present in plots	3 to 5	5 to 12	1 to 7
Total # of NNIS forest floor plant species in plots	0 to 1	2 to 3	0
Total # of native forest floor plant species found in plots	0 to 4	3 to 9	1 to 7

Table B. Severity sites 1-3 flora abundance and species richness raw data ranges**:** based off the 3 plots (raw data: high and low extreme values for all three plots at each site) (Sites 1-3) abundance and species richness highest and lowest values involving each of the three forest strata layers (canopy, shrub/sapling, and forest floor) of each severity site.

Site Overall Species Richness (within 3 plots)	Site 1	Site 2	Site 3
Number of Tree Species (includes all plots: native and NNIS)	5	13	8
Number of Shrub Species (overall)	0	5	0
Number of Sapling Species (overall)	1	8	0
Number of Forest Plant Floor Species (overall)	8	16	11
Number of Native Tree Species	4	11	8
Number of Non-native Invasive Tree Species	1	2	0
Number of Native Shrub Species	0	2	0
Number of Non-native Invasive Shrub Species	0	3	0
Number of Native Sapling Species	1	7	0
Number of Non-Native Sapling Species	0	1	0
Number of Native Forest Floor Plant Species	6	13	11
Number of Non-native Invasive Forest Floor Plant Species	2	3	0

Table C. Severity Sites 1-3 Species Richness Values**:** This table is based off plot raw data #s not averages. This table illustrates the overall species richness values for all three forest stratification layers including the canopy, shrub/sapling, and forest floor involving the categories: trees, shrub/saplings, forest floor plants, native trees, non-native invasive trees, native shrubs, non-native invasive shrubs, native saplings, non-native invasive saplings, native forest floor plants, and non-native invasive forest floor plants for all three invasion severity sites (1-3).



Braun–Blanquet scale	
+	<1% cover
1	1–5% cover
2	6–25% cover
3	26–50% cover
4	51–75% cover
5	76–100% cover

Figure A. The Braun-Blanquet scale used for average percent cover for forest floor plants within each of the three severity sites.