Relative Distribution of Invasive and Native Groundcover Plants in Upstate New York Forests

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Abstract
Invasive plant species can pose a significant threat to forest ecosystems under some circumstances. Forest fragmentation may play a role in this dynamic, because invasive plants establish themselves along forest edges. Studies of the distribution of invasive species are important in order to allocate conservation resources effectively, and guide community development and planning. In this study, we analyze the distribution of invasive groundcover plants and their relationship with native groundcover plants by surveying 264 one meter square test plots across 13 locations in the capital district of Upstate New York. Percent cover exotic and native plant species in each plot were estimated and analyzed digitally. Our data show that as exotic plant cover increases, native plant biodiversity decreases. Our data does not show a strong correlation between the cover of exotic species and native species. We also found that when we removed the most prevalent native plant, *Parthenocissus quinquefolia* (Virginia Creeper) from the analysis of total native cover, the trend between exotic cover and native was slightly stronger. Future work could employ additional metrics such as light penetration and nutrient levels to further explore the competitive relationship between exotic and native plants in a fragmented deciduous forest ecosystem.

Introduction

Invasive plant species are a major concern for certain ecosystems because their invasions can lead to a lack of biodiversity, replace native species, and make ecosystems much less resilient. (Vila et al. 2011), However some ecosystems are more resilient than others and may not need as much effort put towards conservation. In some cases, exotic plants can have positive impacts on critical parts of the ecosystem, such as pollinators. (Kovacs-Hostyanszki et al. 2022). Resilience is especially important now, as many ecosystems are facing new climate extremes. (Ratajczak et al. 2018) Limited resources such as time, money, and labor need to be distributed in a way that maximizes positive environmental impact.

In New York state, 61% of all land is forested. 53% of forests in New York are deciduous forests. (NYS DEC). Forest fragmentation is defined as a loss of forest space due to human activities, as well as the breaking up of forests into smaller sections. (Fahrig 2003). Globally, Seventy percent of forest space is only one kilometer from its edge. (Haddad et al. 2015) This means the temperate deciduous forests that are fragmented make up a significant part of New York State land.

Negative edge effects occur from forest fragmentation when a forest space is divided by human made corridors such as roads, trails and housing developments. Areas along the edges of forests are more susceptible to invasions. (With et al. 2004). There are multiple factors that make forest edges more habitable to new plant species, such as light availability and increased seed dispersal. Seedlings have a higher rate of establishment along forest edges. (Brothers et al. 1992, Hansen et al. 2005) As humans keep developing new land, forests will become more fragmented, allowing for increased spread of invasive exotic plants.

This pattern raises a few key questions. Firstly, what is the distribution of exotic ground cover plants across New York forests? How much space on the forest floor do they occupy compared to native species? Are the exotic species that are present on the forest floor coexisting with native species or are they taking over habitat space that is vital for the survival of native species? Because exotic species are already established, it is difficult to fully answer these questions, but by measuring the occurrence and co-occurrence of exotic and native plants, we can better understand the relationship they have.

Many factors such as concentration of soil nutrients, time of year, soil moisture and levels of light play a role in the relationships between groundcover plants. Before we can examine those factors, we need a basic idea of the groundcover distribution of exotic plants such as *Rosa multiflora* (Multiflora Rose), *Lonicera morrowii,* (Morrow's Honeysuckle), *Celastrus orbiculatus*, (Oriental Bittersweet), and *Rhamnus cathartica* (Common Buckthorn), as well as others. This study aims to explore the relative distribution of exotic and native ground cover plants in temperate deciduous forests in the Capital District of New York State. We investigate the effect of exotic species on the diversity and cover of native species in Upstate New York, in order to determine if native plant species are being significantly affected by the presence of exotic plants. By learning more about the distribution and the effects of exotic plants, we can better understand this prevalent ecosystem's vulnerabilities in order to make more informed policy decisions about exotic species management, forest conservation, and development on a local and regional scale.

Materials and Methods

This study focused on sampling within temperate deciduous secondary forest ecosystems in the Mohawk-Hudson Valley of New York State. All of the test sites were within secondary growth fragmented forests characterized by the presence of roads, housing developments, and trails. All test plots were located less than one kilometer from a road, trail or other man-made pathway or structure. All of these test sites were also kept within a 30 kilometer radius of the first sampling site in order to minimize changes in environmental factors such as elevation and climate, while still allowing for a large sample size. Sites included nature preserves, public land, parks, and private property (with permission). Nature preserves that are actively managed for invasive plants were excluded from this study. This study included 13 sites and 264 test plots. The average number of test plots within a given site was 20.3.

All of the sampling for this study was conducted during August and early September 2023. By this time during the year, most plants are at their peak growth and foliage cover, with the exception of some notable plants such as *Alliaria petiolata* (Garlic Mustard), which peaks in late Spring.

Test sites with a presence of exotic species were chosen for sampling, however, the exact location of the plots within those sites was chosen randomly during sampling. Within each site, sample plots were taken in areas of the land that resembled the deciduous secondary forest ecosystem, excluding wetlands, meadows, and coniferous dominated areas. Dominant tree species at each site were noted.

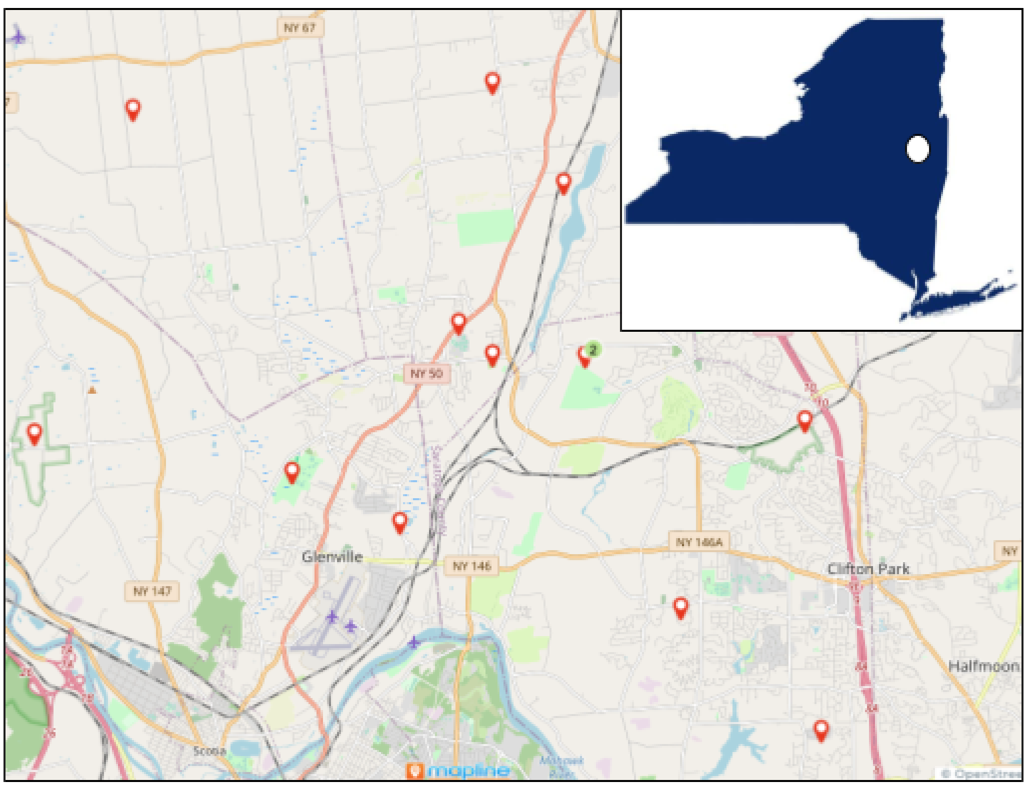

Figure 1. Map of field sites sampled. Pins with a number show that two sites were close. (Rieffel, Simon. Map of sampling sites. *Mapline,* 23 October 2023.) Insert depicts the region of New York State where sampling was conducted. (New York State Government. "New York State Blue Map.jpg". *Wikimedia Commons*, 16 October 2022, https://commons.wikimedia.org/wiki/File:New_York_State_Blue_Map.jpg

I placed a 1 meter by 1 meter square plot made of PVC piping on the ground at each plot location. Species were identified using the Seek by Inaturalist mobile app (version 2.15.0) and confirmed by expert opinion, reviewing digital photos from the Inaturalist database and guidebooks. Percent cover for each plant species was recorded as one of the following categories: <1%, 1-5%, 5-10%, 10-25%, 25-50%, 50-75%, and 75-100%. If leaves overlapped, total cover of the plot could exceed 100%. All plants counted whether they had roots/stem inside the plot, as long as some part of the plant was in the plot. Plants that were over one meter tall were excluded, because they were large shrubs or trees and not ground cover plants.

During sampling, I noted certain plants that had to be marked “unidentified”. The unidentified plants could not be identified because they were too small, impossible to distinguish without flowers, or damaged by insects, animals or other natural causes. Although these plants could not be identified at a species level, a genus was identified in most cases and the plant was placed into the exotic or the native category.

Data were recorded in a lab notebook, and then manually entered into a Google spreadsheet. Analysis was performed using Google Sheets and Microsoft Excel. Percent ranges that had been estimated during data collection were averaged for the sake of data analysis.

The total cover of native and exotic plants for each plot was calculated as follows: first, plants were categorized as either native or exotic, then the total cover of native and exotic plants was added up for each plot.

The Shannon-Weiner Species Diversity Index (Nolan et. al 2006) was used to represent the biodiversity of native species in test plots. The index calculation involves taking the number of each species and the proportion of each species to the total number of individual species, multiplying the proportion times the natural log of the proportion and then adding up all the values in every plot. It is calculated using the following equation:

$$H' = -\sum_{i=1}^{p} p_i \ln p_i$$

Linear regression analyses and covariance analyses were performed to analyze the relationships between total exotic plant cover and total native plant cover, as well as between total exotic cover and the number of native species in plots. Linear regression and covariance analyses were also calculated for the relationship between total exotic cover of test plots and native plant species diversity using the Shannon-Weiner Diversity index.

Results

In total, 170 different taxa were identified across 264 test plots at 13 research sites. (Figure 1). This included 13 distinct exotic species, 126 distinct native species, 1 unidentified exotic taxa, 20 unidentified native taxa, and 10 unidentified unknown taxa. The 20 most prevalent species are listed in Table 1.

Latin Name	Common Name	Plant status	Occurrence (# of plots)	Avg. % cover
Parthenocissus quinquefolia	Virginia creeper	Native	150	29.7
Celastrus orbiculatus	Oriental Bittersweet	Exotic	86	15.2
Onoclea sensibilis	Sensitive Fern	Native	67	17.4
Rhamnus cathartica	Common Buckthorn	Exotic	55	6.6
Fraxinus americana	White Ash	Native	51	12.2
Rosa multiflora	Multiflora rose	Exotic	45	19.6
Lonicera morrowii	Morrow's Honeysuckle	Exotic	42	21.9
Toxicodendron radicans	Poison Ivy	Native	40	6.12
solidago	Goldenrods	Undetermined	33	10.8
Cornus	Dogwoods	Undetermined	31	5.64
Fragaria virginiana	Virginia Strawberry	Native	28	5.1
Circaea lutetiana	Broadleaf Enchanter's Nightshade	Native	27	18.6
Impatiens capensis	Common Jewelweed	Native	28	3.2
Geum canadense	White Avens	Native	27	3.1
Galium triflorum	Fragrant Bedstraw	Native	26	2.4
Symphyotrichum lateriflorum	Calico Aster	Native	26	2.8
Rubus	Brambles	Undetermined	25	9.5
carex	True Sedges	Undetermined	24	10.5
Acer Rubrum	Red Maple	Native	22	1.9

Table 1. The 20 most prevalent species and taxa that were identified in the test plots, their exotic/native status, the number of plots they appeared in, the average percent of a 1x1 meter plot that the plant occupied when present.

The average total plant cover of test plots was 60%, with native plants accounting for 42% and exotic plants accounting for 14%. The remaining 4% was unidentified. The most prevalent native plant was *Parthenocissus quinquefolia* (Virginia Creeper), occupying space in 150 different test plots. It also had the highest average percent plot cover out of all of the 75 most prevalent species. Four different exotic species, *Celastrus orbiculatus* (Oriental Bittersweet), *Rhamnus cathartica* (Common Buckthorn), *Rosa multiflora* (Multiflora Rose), and *Lonicera morrowii* (Morrow's Honeysuckle) were among the 10 most prevalent species observed in the test plots.

The average percent cover of all exotic species when they occurred (15.02%) was higher than the average percent cover of all native species (11.55%). This means that when they occurred, exotic species took up more space than native species.

Covariance between total exotic cover of test plots and total native cover of the plots shows a negative relationship. (-72.87). This indicates that as exotic plant cover increases, native plant cover decreases. In addition, the regression analysis ($R^2 = 0.01$) indicates a slight trend between the variables. However, the P value is insignificant ($p = 0.11$) (Figure 2.The same test was conducted, excluding Virginia Creeper cover from total native cover, and the trend was still insignificant, but less so than when Virginia Creeper was included ($R^2 = 0.01$, $p = 0.072$)

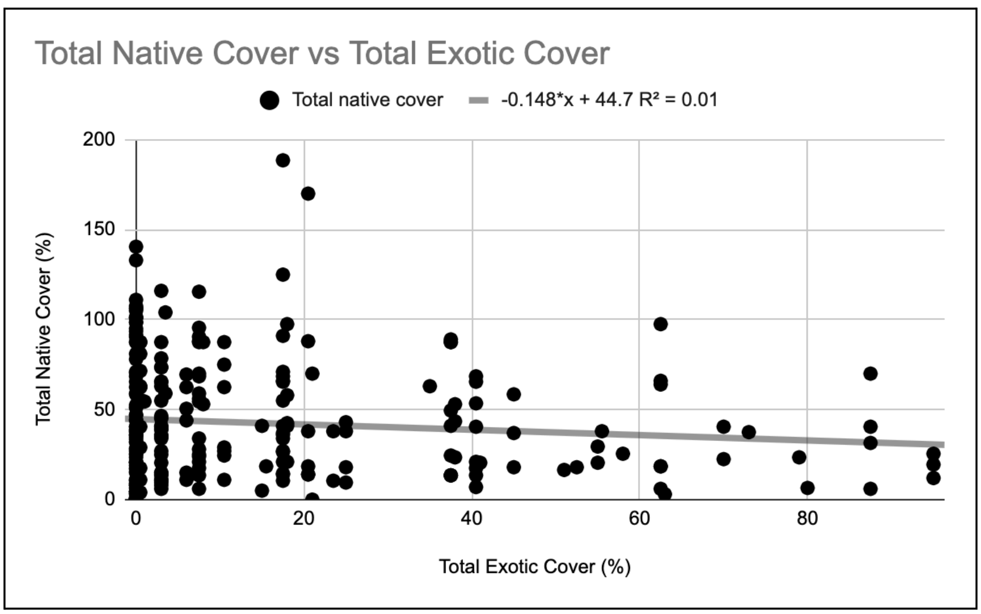

Figure 2. Regression Analysis of total exotic cover within plots and total native cover within plots.

The total number of native species in each test plot was compared to the total percent exotic cover. Covariance analysis indicated a negative covariance between these two datasets (-1.83). However, the regression analysis did not show a significant relationship between the total exotic cover of plots and the number of native plant species ($R^2 = 0.002$, $p = 0.512$) (Figure 3).

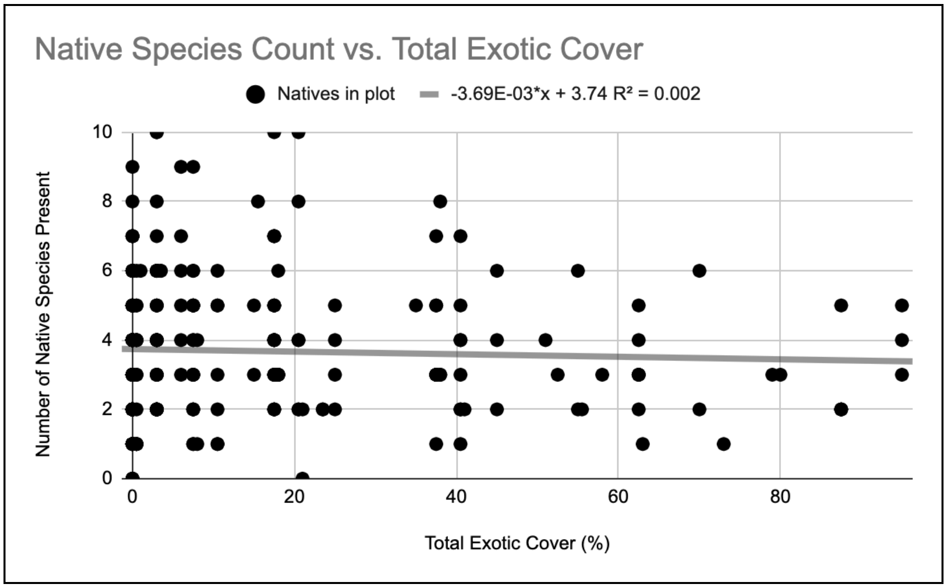

Figure 3. A comparison of total exotic plant cover in test plots with the number of native species present.

Another way to measure the native plant biodiversity in test plots is using the Shannon-Weiner Diversity Index. This method takes into account the percent cover the native plants occupy as well as the number of native species in a plot. Using this Diversity Index instead of the number of native species in each plot, the data indicated a significant negative correlation between total exotic cover and native plant diversity ($R^2 = 0.019$, $p = 0.024$) (Figure 4). The covariance between these two datasets also indicates a negative relationship (-1.29).

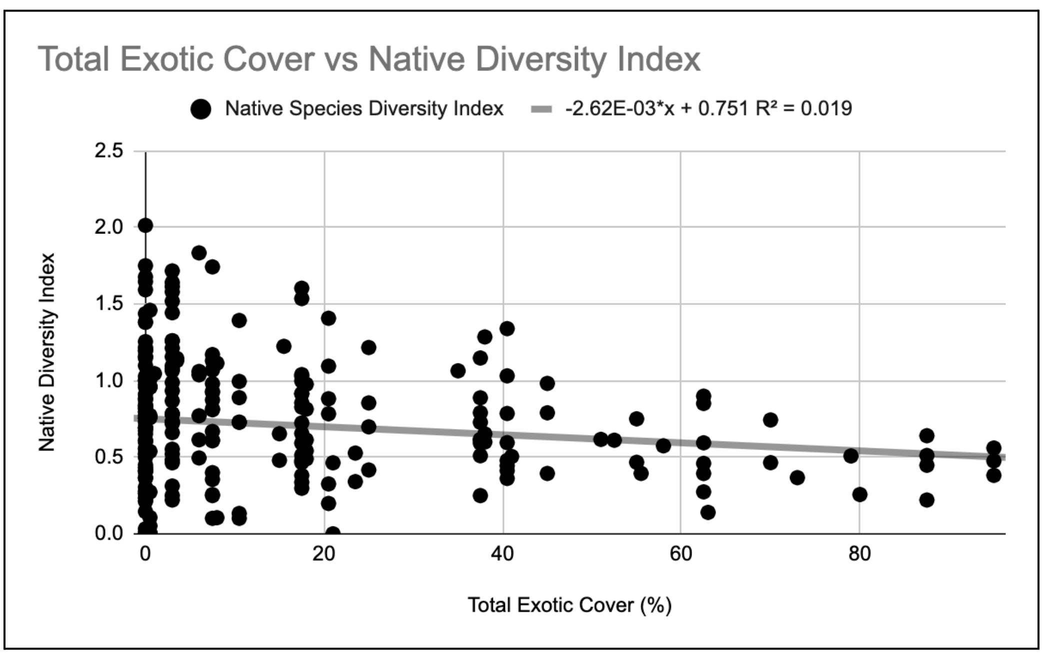

Figure 4. Comparison of Total Exotic Cover with total Native Diversity Index, as calculated using the Shannon-Weiner Diversity Species Index formula. (Nolan et. al 2006) As percent exotic cover increased, native diversity decreased.

The most prevalent native species, *Parthenocissus quinquefolia* (Virginia Creeper), was compared to the total native cover without *P. quinquefolia*. As cover of *P. quinquefolia* increased, total native cover decreased ($R^2 = 0.06$, $p < .001$). *P. quinquefolia* cover was also compared to the diversity index of native species in plots. There was no significant correlation ($R^2 < .001$, $p = 0.83$).

Discussion

The plants that occupy the understory of forests change throughout the year. The data used in this study were collected in the month of August, because plants have had time to grow and establish themselves for the year. At this time, the invasive plant *Alliaria petiolata* (Garlic Mustard), had already flowered, seeded, and died back. This would have influenced the percent cover of exotic plants significantly. Certain native plants, such as most of the plants in the *Solidago* genus (Goldenrods), had not yet flowered at the time of the study. However, perennial plants and those with woody stems, such as *Lonicera* honeysuckles, most likely remain constant in their percent cover throughout the spring and summer.

Our findings indicate that as exotic plant cover increases, native plant cover decreases. However, the P value ($p = 0.11$) suggests that this is not a significant trend or relationship. This may be due to the broad percent cover ranges that plants in plots were put into. These groups were chosen because it was the most precise possible without spending a significantly longer time in the field measuring plants in test plots. This efficiency facilitated a larger sample size, but limited the ability to measure cover more precisely. This lack of a significant relationship between native and exotic plant cover may also be caused by an abundance of resources and space on the forest floor. Our data shows that the average percent of test plots that was occupied by plant cover was 60%, leaving the remaining 40% unoccupied.

When the most abundant native plant, *Parthenocissus quinquefolia*, was excluded from total native cover and the same analysis was conducted, the relationship between native and exotic plant cover was still insignificant, but was a more notable trend than when it was included ($p= 0.072$).

When *P. quinquefolia* cover was compared to total native cover without *P. quinquefolia*, we found that total native cover decreased as total native cover increased ($p= <0.001$). This makes sense because v*P. quinquefolia* had the highest average cover among the most common native species seen in test plots. It did not have the highest average percent cover, because seven plants that occurred in test plots two times or less, had average cover of over 50%. Most of these were species of ferns that occur in large patches.

Notably, although Virginia Creeper occupied a large amount of space in the test plots, there was no significant relationship between Virginia Creeper cover and the native species diversity index ($p= 0.83$). Further work may explore the possibility that Virginia Creeper is more competitive in this habitat than other native species, and may obscure the competitive pressures that other native species face.

Exotic species cover did not have a significant impact on the absolute number of native species in each plot ($p= 0.512$). When the total exotic cover was compared to the Shannon-Weiner Diversity Index for each plot, exotic cover did have a statistically significant impact on native plant species diversity ($p=0.024$). This finding supports the hypothesis that as exotic plant cover increases, native plant biodiversity decreases. According to the data we collected, exotic plant cover does not cause a noticeable decline in the number native species or the percent cover of native species, but when both of these are taken into account using the Shannon-Weiner Diversity Index, exotic plant cover decreases biodiversity of native plant species. This finding has relevance for invasive species management efforts, which should take into account the protection of ecosystems' biodiversity as well as the simple abundance or paucity of native plants.

Future work may explore the relationship between native and exotic ground cover plant species at different times of year, and possibly using different methods of sampling that allow for a larger area of the forest to be surveyed in order to more accurately represent the scale of the forest floor. Exotic plant cover during the Spring season may be significantly higher because of the presence of Garlic Mustard. The relationship between exotic and native plant species may be different in areas of forest that are not fragmented. Additional metrics such as soil sampling to measure available nutrients, as well as light penetration on the forest floor may be useful to further investigate this competitive relationship and what influences it.

Conclusion

This study explored the relative distribution of exotic and native ground cover plants in fragmented temperate deciduous forests in the capital district of New York State. The most prevalent native species was Virginia Creeper, and the most prevalent exotic species was Oriental Bittersweet. We investigated the effect of exotic species on the diversity and cover of native species. According to the data we collected, exotic plant cover does not cause a noticeable decline in the number native species or the percent cover of native species, but when both of these are taken into account using the Shannon-Weiner Diversity Index, we found that an increase in exotic plant correlated to a decrease in biodiversity of native plant species. This finding has implications for policy decisions about exotic species management, forest conservation, and development on a local and regional scale. Future investigation may explore the relationship between native and exotic ground cover plant species at different times of year. Other metrics such as soil nutrient levels and light penetration may further elucidate the relationship between exotic and native ground cover plants in this ecosystem.

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