Original Research Article

An understory comparison of the exotic *Phellodendron amurense* Rupr. (RUTACEAE) and adjacent native canopy species in an urban and suburban woodland

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ABSTRACT

An understory comparison of the invasive tree species *Phellodendron amurense* Rupr. and surrounding native tree species at two locations in the greater New York metropolitan region is examined. The understory of canopies consisting of *P. amurense* was compared with adjacent canopies consisting of native tree species based upon their species, density, richness and native understory composition. To determine if differences can be accounted for by shade cast by the canopy, leaf area indices were compared between the two canopy types at both locations.

At both locations there was a significantly lower number of individual plants per m^2 quadrat under *P. amurense* than under native canopy. When looking at only native understory species, there was also a highly significant difference with *P. amurense* canopies having lower numbers of native individuals present per quadrat. There was also a significant difference between the invaded versus native sites in the mean number of total species per m^2 quadrat at both locations.

Canopy Analysis revealed no significant differences in leaf area index between canopy types at either site although leaf area index was higher under native species at both locations indicating that shading is not likely to play a role in the lower density of understory individuals under *P. amurense.*

Keywords: Phellodendron, Rutaceae, Invasive species, Urban forests

1. INTRODUCTION

Human introductions of new species to ecosystems, both accidental and intentional, can have numerous unintended consequences [1, 2]. Since the publication of Charles Elton's *The ecology of invasions by animals and plants* in 1958 [3], much more attention has been paid to the problem of non native introduced species, as well as their ecological and economical costs. However, as species are introduced to new regions of the globe each year, research into the impact and spread of each of these new invaders is often lacking and lags behind any potential point at which a problematic invader can be controlled effectively.

In the northeastern United States, the non native *Phellodendron amurense* Rupr. (Rutaceae), known commonly as Chinese or Amur cork tree, has invaded a number of forested sites in both urban and suburban woodlands [4,5]. Introduced to North America in 1856, *P. amurense* is a dioecious tree growing to 38m in height, is free of pests and withstands a variety of conditions making the tree excellent for parks and large landscapes [6]. These characteristics make the tree an excellent choice for many horticultural situations and have resulted in *P. amurense* being cultivated throughout the United States, particularly in public gardens and arboreta as summarized by Ma and Branch [7]. Numerous horticultural collections and introductions such as this have resulted in the spread of many invasive plant species in the United States [8] including *Schinus terebinthifolius* Raddi. (Brazilian peppertree) in Florida and *Acer platanoides* L. (Norway maple) throughout the northeastern United States. Currently *P. amurense* appears to be spreading throughout the lower northeastern region [4] and is likely to join this growing list of aggressive invaders.

Prior to a recent revision of the genus *Phellodendron* [9], the species may have been overlooked as an introduced member of the local flora due to confusion in the nomenclature. Greller [10] and Bertin et al. [11] both reported *P. japonicum*, a species now included within the variable *P. amurense*, as a part of their floristic works in the northeastern region. de la Cruz and Nee [12] report the entire genus *Phellodendron* as aggressively invading the hemlock forest of the New York Botanical Garden, Bronx County, New York. Their work reports that cultivated collections at the New York Botanical Garden contained *P. amurense*, *P. chinense*, *P. japonicum*, *P. lavallei* and *P. sachalinense*. With the exception of *P. chinense*, the additional four species have all now been designated as *P. amurense* [9]. At the site of a large invasion within the hemlock forest of the New York Botanical Garden, the *P. amurense* population has shown wide diversity in its morphology in both the leaflet base shape and the leaflet tomentum, [12] possible character differences which may continue to lead to confusion in correctly identifying this species. With the recent clarity given to this genera's taxonomy, it is very likely that the species will be recognized as a more common component of the regional flora.

In recent years, studies have begun to address the impacts of established invasive plant species through comparative analyses of invaded and non invaded habitats by a particular species [13,14]. These ecological impacts consist of any significant change in an ecological pattern or process [15], such as the changes examined within this work. However, this type of assessment has only been done for a small percentage of the many plant species which have now been introduced into new regions, and even fewer studies have been done upon the impact of species not yet fully recognized as widespread invasive species. A major challenge to the management of invasive species is the conveyance of information to the public [16], a process that may be on hold in many instances until those threats are understood.

As a result of working with *P. amurense* invasions over the past several seasons, we hypothesized that the understory flora of these areas had lower species richness, lower overall individual abundances and contained a lower percentage of native species than adjacent areas of the same forest which did not contain *P. amurense* trees. We also attempted to gain insight of reasons for a difference in understory by measuring the leaf area index of both the *P. amurense* and adjacent non *P. amurense* canopy, enabling us to determine if a difference in shading could lead to differences in the understory composition. To assess the impact of *P. amurense* upon the understory flora of areas which have been invaded, a quadrat based analysis comparing invaded versus adjacent uninvaded areas in two separate forests was performed. An analysis of the canopy was then performed by using hemispherical canopy photographs in the sampled areas.

2. MATERIAL AND METHODS

This study was conducted in the summer of 2009 at two sites where invasions of *P. amurense* totaling more than 100 mature trees were present. Site 1 is located within the forested portion of the Bartlett Arboretum, Fairfield County, Connecticut (41.07'N 73.33'W) and consists of 31 hectares of forested lands within a public arboretum managed by a private not for profit corporation. Site 2 is located at Forest Park, Queens County, New York (40.42'N 73.51'W) and is 220 hectares of predominantly forested lands and is owned and operated by the City of New York Department of Parks. Both the Bartlett Arboretum [17] and Forest Park [10, 18] has vegetation which has been documented prior to this analysis. As measured in importance values, Morgan [17] describes the surrounding forest of the Bartlett Arboretum in its entirety to be dominated by *Fagus grandifolia* Ehrh., *Acer rubrum* L. and *Betula lenta* L. Greller et al [10], describes the forest of Forest Park in its entirety as dominated by *Quercus rubra* L., *Q. velutina* Lam., and *Q. alba* L.

To assess the understory vegetation at each site, a transect was drawn through the *P. amurense* invaded sections of the forest. The understory consisted of all herbaceous and woody species not reaching 1.3m in height, a method previously used at this site by Greller *et al*.[10]. Along this transect individuals of *P. amurense* within 5 m on either side of the transect, measuring at least 5 cm diameter at breast height (DBH) were selected, and four plots measuring 1m^2 were placed directly North, South, East and West of the tree with the center of the sample plot being 1.5m from the trunk edge. *P. amurense* trees were chosen by their proximity to the transect, and those which resulted in overlapping plots were eliminated. This resulted in 72 plots being analyzed at the Bartlett Arboretum and at Forest Park 96 plots were analyzed for a total of 168 plots under *P. amurense* canopy. To select plots in non invaded areas for comparison, a similar transect was drawn in an area immediately adjacent to each invaded site. At both locations, the non invaded sections were intermittent with the invaded sections of each site. No visible difference in elevation or soil moisture levels were apparent through visual observation. Along this line a similar procedure was used, however *Betula lenta* was substituted for *P. amurense*. At both sites, *B. lenta* had been documented as a major component of the forest in importance value. At the Bartlett Arboretum, 84 plots under *B. lenta* were analyzed and 52 at Forest Park for a total of 136 plots under native canopy. This resulted in a total of 304 plots of one square meter being measured at both sites and under all conditions.

Within each plot all vascular plants were identified to species and the number of individuals recorded. No *P. amurense* or *B. lenta* were found within the understory sampling plots, a convenience which eliminated any potential impact of spatial autocorrelation. To ensure adequate sampling, plots were created in late May 2009 when the original surveys were conducted and were repeatedly examined at least once per month over the summer season to account for newly emerged plants. Plot borders were marked with nylon flags to ensure the exact sited were measured each survey. For several prostrate species where individual species counts were difficult, the 1m^2 plot was further divided into one hundred 10 cm by 10 cm subplots and an individual was tallied for each of these subplots the plant occurred within.

To analyze the canopy a CI-110 digital plant canopy imager, (CID Inc. Camas, WA) was used. Data was collected in July 2009 through the creation of hemispherical canopy photographs which were analyzed for calculations of leaf area index. To obtain this data, the imager was used by collecting images along the same transects as used for the creation of plots. To assure canopies were not duplicated in the analysis; images were taken at least 20 m apart in both *P. amurense* invaded and non invaded areas. This resulted in twelve photographs of the native Canopy at the Bartlett Arboretum and eight of the *P. amurense* canopy. Due to the large areas captured by each photograph, the possibility of photographing each sample tree was not possible since it would have led to extensive duplication in the canopy areas sampled. After the original LAI analysis was performed, a second set of data was taken at the Bartlett Arboretum six weeks later to look for changes in significance of the results over a season. At Forest Park, fourteen photographs were taken under native canopy and twelve under *P. amurense*.

All data was analyzed using JMP 8.0.1 [19].

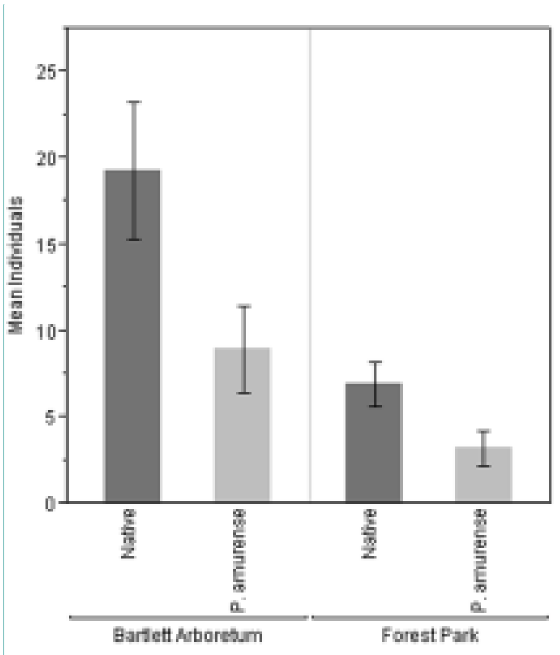
Comment [U1]: The software is not important, you need to tell which was the hypothesis test!

3. RESULTS

Understory Individual Density. At both the Bartlett Arboretum and Forest Park sites, understory individual density differed significantly with the understory of native *B. lenta* having more individuals than the *P. amurense* understory. In all cases sites were compared individually based upon native versus *P. amurense* canopy through the use of a t-test. At the Bartlett Arboretum mean understory individuals per m^2 measured 19.29 under the native canopy and 8.95 under *P. amurense* (P = .0001). Forest Park, mean understory individuals measured 6.92 under the native canopy and 3.23 under *P. amurense* (P = .0001). These results are demonstrated in Figure 1.

Comment [U2]: If not compared between sites, may be T or U test (two quantitative variables).

Figure 1.



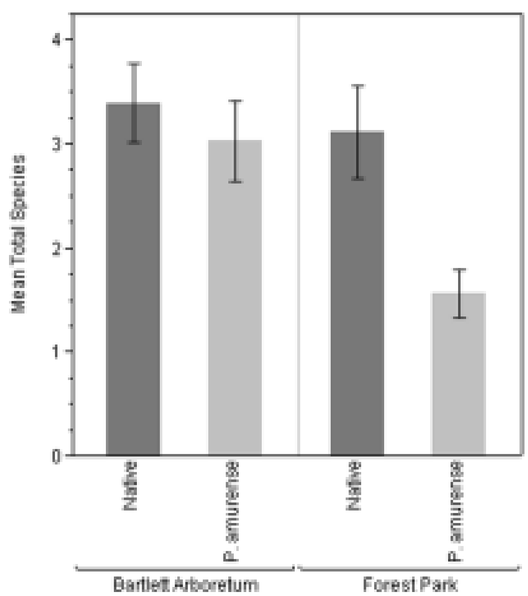
Comment [U3]: I believe a single table containing the four parameters evaluated would be more useful. Could put: mean, mode and standard deviation.

The charts are useful if you aim which was the hypothesis test!

Mean number of total individuals per quadrat of all species under each canopy type at each site. Error Bars represent 95% confidence intervals.

Total Species Richness. At the Bartlett Arboretum site, species richness per quadrat was significantly higher under the native canopy (3.39 species) than under *P. amurense* canopy (3.03 species), (P = .0001). At the Forest Park site a significant difference existed with mean species richness under native canopy trees measuring 3.11 species and mean species richness under *P. amurense* measuring 1.56 species (P = .0001). Both sites were analyzed by the use of a t-test. These results are demonstrated in Figure 2. In total, 43 species were identified under *P. amurense* at the Bartlett Arboretum and 44 under native canopies. At forest Park a total of 27 species were identified under *P. amurense* and 32 under native species.

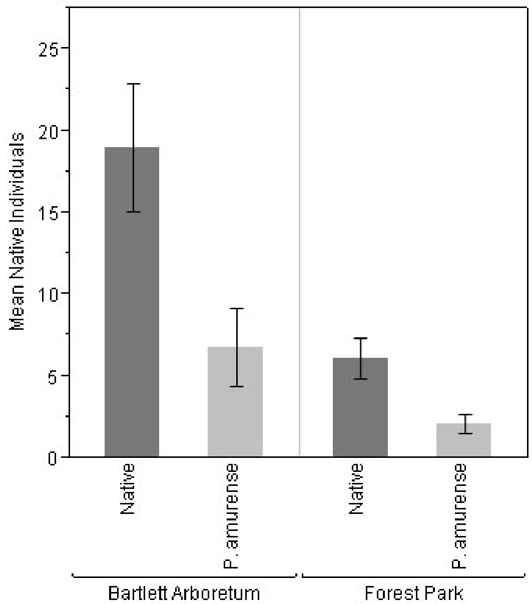
Figure 2.



Mean number of total species per quadrat under each canopy type at each site. Error bars represent 95% confidence intervals.

Total Native Individuals. At both sites, a significant difference existed within each site between the number of native individuals per quadrat under native canopy versus *P. amurense* canopy with more native individuals being present under native canopy. At the Bartlett Arboretum, mean native individuals measured 19.00 under the native canopy while measuring 6.75 individuals under *P. amurense* P = .0001). Forest Park mean native individuals measured 6.11 under native canopy and 2.08 under *P. amurense* canopy (P = .0001). These results are demonstrated in Figure 3.

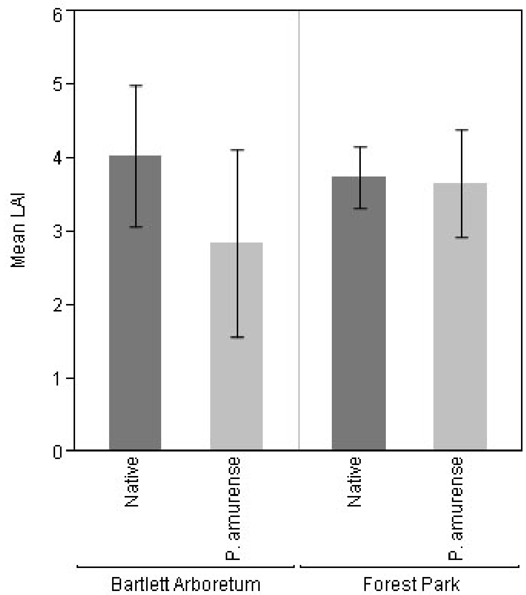
Figure 3.



Mean number of total native individuals per quadrat under each canopy type at each site. Error bars represent 95% confidence intervals.

Canopy Analysis. Comparisons of the canopy of *P. amurense* invaded versus non invaded areas showed no significant difference in leaf area index for the Bartlett Arboretum site or Forest Park. Leaf Area Index (LAI) at the Bartlett Arboretum measured 2.839 under *P. amurense* canopy and 4.020 under native canopy P = .1071) at the time of the first measurements. At Forest Park, LAI measured 3.642 under *P. amurense* canopy and 3.727 under native canopy (P = .8287). These results are demonstrated in Figure 4. The second set of measurements resulted in a LAI of 2.433 under *P. amurense* canopy of and 2.348 under native canopy (P = .5830). These later results reaffirm the non significant differences in the early canopy photographs and are not included in Figure 4.

Figure 4.



Mean leaf area index under each canopy type at each site. Error Bars represent 95% confidence intervals**.**

Our results support the hypothesis that *P. amurense* understory composition will have lower overall individual abundances, lower species richness and contain a lower percentage of native species than adjacent areas of the same forest not containing *P. amurense*. However, these results do not provide insight into the mechanism by which this process occurs. Specifically, we find no significant differences in the level of leaf area index between native canopy and that of *P. amurense*.

4. DISCUSSION

Invasive plant species are well documented to have negative effects upon the native plants of the area into which they invade [13, 20, 21] as well as impacts upon the entire community [1,22]. Many invasive species go unnoticed as members of the communities until they have reached levels which are no longer easily controlled.

The spread of *Phellodendron amurense* into the forests of the northeastern United States has the potential to affect both the richness and abundance of the surrounding flora. With the pronounced differences reported here upon the number of native individuals between canopy types, this invasion is likely to impact native populations of plants more than other individuals which are naturalized from outside the region. While this work shows a significant difference between the understory density of native plants between the two canopies, there is still the question of whether the *P. amurense* trees caused this difference, or if they invaded upon degraded sites with a prior difference in understory composition due to factors such as soil quality or disturbance. These results provide the first step in identifying a problem and show the strong need for further assessment of this invasive tree species.

The appearance of a lower density of individuals in areas invaded by *P. amurense* was the initial visual clue leading to this study although only the visual assessments, not numerical evidence was present prior to this work. This statistically lower density under *P. amurense* at both sites reported here confirms our hypothesis of lower density, and showed that across both sites (Bartlett 19.28 native canopy, 8.9 *P. amurense* canopy and Forest Park 6.92 native canopy, 3.22 *P. amurense* canopy), the trend of lower individuals under *P. amurense* remains consistent even though the level of individual density varied between the two.

Shading is often reported in secondary publications to be the cause in the case of other invasive tree species and their impact upon the understory [23], however we find no evidence of a significant difference in shade cast between the surrounding native canopy and that created by mature trees of *P. amurense* when measured using leaf area index. Visual observations also indicate that the leaves of *P. amurense* at both locations fully emerge eight or more days after all the species in the adjacent native canopies. This would eliminate earlier leaf emergence, and consequentially earlier shading by *P. amurense* as a factor in the understory differences that are reported here.

Most importantly, these results indicate that there is a strong need for addressing the invasion of *P. amurense* in the forested areas of the northeastern United States. While the exact causes of the decreased number of native individuals and lower species richness under *P. amurense* is undetermined, these results highlight the importance for more aggressive monitoring of this and other invasive species not yet targeted by government and private agencies, as well as the importance of control and removal programs in affected areas.

5. CONCLUSION

Further study of *P. amurense* is needed to establish the mechanisms by which the lower understory native individuals and species richness occurs. Additionally, an investigation into the biological attributes of *P. amurense* such as seed production, dispersal, seedling survival, allelopathic potential, and growth rates all need to be further examined in this potentially high impact invader. Recent work to address the question of allelopathy has been performed in a laboratory setting [24], but whether this may play in an ecological context remains to be seen.

The demographic processes of successful invading organisms may result in the alteration of the character or community of a landscape [25]. This work begins to address some of the many questions that currently prevent a full understanding of the importance, significance and potential severity of further invasion by *P. amurense* into the forests of the region.

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