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Research Note

Suburban gardening in Rochester, New York: Exotic plant preference and risk of invasion

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ABSTRACT

Horticulture has long been an important source of exotic plant species that may naturalize and become invasive. To analyze the extent of exotic plant species and their possible preference in modern landscaping in Rochester, New York, USA, we inventoried 101 randomly chosen suburban (peri-urban) house gardens. On average, 72% of plants per property were not native to the Eastern United States. Of the exotic species present in gardens, 44% have naturalized in New York State. Additionally, invasive plants were often intentionally planted, such as Japanese barberry (*Berberis thunbergii*), which was found in nearly half of the gardens. We also sought to ascertain if garden diversity could be correlated with the age, size, or cost of properties. Although our findings were not as distinct as previous garden inventories, property size and mortgage value correlated positively with species richness. Overall, landscape trends across all property types favored exotic over native garden plants.

1. Introduction

Exotic invasive species are considered one of the most significant threats to native species diversity and ecosystem function. Invasive plants have many demonstrated impacts in ecosystems, affecting their ability to provide ecosystem services including, but not limited to, water purification, pollination, and soil stabilization (Pejchar & Mooney, 2009). Invasive plants come at the economic cost of approximately 34.6 billion US dollars per year (Pimentel, Zuniga, & Morrison, 2005). Certain plant species, such as Melaleuca, are considered ecological villains, costing the state of Florida upward of $6 million per year in control measures (Pimentel, Lach, Zuniga, & Morrison, 2000).

At least 50% of the naturalized flora in the United States were deliberately introduced (Mack & Erneberg, 2002), while 82% of the current invasive woody taxa were introduced strictly for horticultural purposes (Reichard & White, 2001). Plant species have been grown and traded for ornamental purposes dating as far back as the 20th century BCE China (Zhou, 1994). In North America, nurseries were initiated as early as 1737 (Manks, 1968), with concerted efforts by nurserymen and plant explorers to introduce exotic plants in the 18th and 19th centuries (Manks, 1968). Only recently have invasive species been targeted for enforcement and regulation in some areas of the US, such as New York. Regulation 6 NYCRR Part 575 (NYCRR, 2017) now prohibits the sale of 70 plant species and regulates six. Such regulations are needed to slow the influx of potentially invasive species, as plant traits that are desirable to both horticultural and consumer groups such as drought tolerance, hardiness, ease of propagation, and rapid growth also make species formidable invaders in natural areas (Bell, Wilen, & Stanton, 2003).

Despite efforts to decelerate introduction of new species, it is likely that gardens in New York are already a reservoir of potentially exotic invasive species. Garden inventories in the United Kingdom (Smith, Thompson, Hodgson, Warren, & Gaston, 2006), France (Marco et al., 2008), and Burundi (Bigirimana, Bogaert, De Cannière, Bigendako, & Parmentier, 2012) showed that exotic species constituted anywhere from 70 to 88% of the flora within private household gardens, with some species representing a high risk for naturalization and invasion. However, not all gardens may house the same types of species. These inventories demonstrated that species assemblages often correlated with socioeconomic standing and garden area. Furthermore, a "luxury effect" has been used to describe the apparent link between wealth status and plant diversity in urban areas (Hope et al., 2003). Additionally, decreased economic resource availability can shape garden diversity, shifting ornamental dominance to that of a utilitarian use of agronomic plants (Bigirimana et al., 2012). Given the varying findings of garden inventories across broad geographical areas, we sought to determine how gardens in a major metropolitan region of upstate New

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York compared.

Our objectives were two-fold. First, we sought to evaluate the preference for exotic species in the garden flora of an upstate New York State metropolitan area, with a focus on species that have recently become state regulated or are potentially invasive. Second, we sought to quantify relationships between garden characteristics and diversity, hypothesizing that larger and more affluent properties would contain higher plant diversity.

2. Methods

In the summer of 2015, we sampled 101 suburban gardens (Appendix C) within the third-largest metropolitan area of New York State: Rochester, NY, with a population of approximately 1.08 million residents (U.S. Census Bureau, 2015). It comprises five counties and is located along the southwestern shore of Lake Ontario in upstate New York. We sampled 101 gardens split across two neighborhood types: suburban and mobile home developments. Sampling occurred primarily in Monroe and Ontario Counties. Suburban homes in this study refer to houses that were typically larger and built on site, whereas mobile (or manufactured) homes were typically smaller, prefabricated, and transported to the site of residency. Houses were initially chosen at random; however, if property owners were absent or they did not grant permission we sampled the next closest available residence. Less than 10% of all homeowners did not grant permission to sample properties. A total of 101 properties were sampled, representing a range of property values from 120,000 to 1,056,440 US dollars, which were approximated via Zillow estimates (Zestimate, 2015). These data were only available for 87 of 101 properties (Zestimate, 2015); therefore, 14 properties were not used in the analyses concerning property characteristics. For NMDS ordination, mortgage values were split equally into four categories across the range of values with group one representing the lowest mortgage values and group four representing the highest values. Property sizes ranged from 404.7 m^2 to 18,575.1 m^2 (0.1 acres–4.59 acres), and property age ranged from one to 61 years since construction. To collect inventories, we followed all edges of the cultivated ornamental portions of gardens, noting all species that had been clearly planted in gardens and trees planted within lawns. Species were then identified to the lowest possible taxonomic level; however, only those species that were confidently identified to genus, species, or cultivar (cultivated variety) level were included in analyses.

Species origin for all woody taxa (tree, shrub, and vine) were determined via Dirr (2009), naturalizations via The New York Flora Atlas (Weldy, Werier, & Nelson, 2018), and updated taxonomy and taxonomic authority determined via The Plant (2013). For herbaceous species, only accepted names for species and family were used via The Plant (2013), eFloras (2008) and WCSP (2018). Species were considered non-native to the Eastern United States if any of their historical range did not include some area east of the Mississippi river (Missouri Botanical Garden, 2018; Dirr, 2009; eFloras, 2008; Gleason & Cronquist, 1991; WCSP, 2018; Weldy et al., 2018). Species were determined native or non-native and naturalized to New York based upon The New York Flora Atlas (Weldy et al., 2018). Origin of exotic herbaceous species was determined via Flora of China and Flora of North America (eFloras, 2008), or Missouri Botanical Garden (2018) and WCSP (2018) if information was unavailable. Certain genera (e.g. *Hosta*, *Hemerocallis*, *Paeonia*) were considered exotic because, of these three genera, only *Paeonia* has representatives in the US; however, these ranges fall far west of the Eastern native boundaries set (eFloras, 2008). Hybrid cultivars with parent species from both native and exotic origins (e.g. *Taxus x media*; *Rhododendron 'P.J.M.'*) were considered exotic. Several genera (e.g. *Rosa*, *Malus*, *Clematis*, *Iris*, *Geranium,* etc…) did not have a known origin due to the extensive history of horticultural hybridization; thus, origin was listed as unknown. If cultivar could be determined, it was recorded and listed after taxonomic authority in single quotes (Appendix A).

Table 1
Twenty-five most frequently planted ornamental plant taxa of gardens in Rochester, NY. F refers to frequency of planting for 101 total gardens. Taxonomic family associated with species is denoted by Family, Strata refers to species growth type, and Origin refers to the area where species is native to. Bolded lines of text represent species native to the Eastern United States (E. US). W. US refers to Western United States. Total number of distinct taxa is 356; however, origin was only determined for 344. See Appendix A for taxonomic notes, corresponding footnote text, and full taxa list.

Taxa	F	Family	Strata	Origin
Hemerocallis sp.[10]	62	Asphodelaceae	Herb	Eurasia
Hosta sp.[11]	61	Asparagaceae	Herb	Asia
Acer palmatum Thunb.	57	Sapindaceae	Tree	Asia
Berberis thunbergii DC.	48	Berberidaceae	Shrub	Asia
Spiraea japonica L.f.	46	Rosaceae	Shrub	Asia
Hydrangea macrophylla (Thunb.) Ser.	44	Hydrangeaceae	Shrub	Asia
Miscanthus sinensis Andersson	40	Poaceae	Graminoid	Asia
Buxus microphylla Siebold & Zucc.	39	Buxaceae	Shrub	Asia
Euonymus alatus (Thunb.) Sieb.	38	Celastraceae	Shrub	Asia
Picea pungens Engelm.	38	Pinaceae	Tree	W. US
Chamaecyparis pisifera (Sieb. & Zucc.) Endl.	36	Cupressaceae	Tree	Asia
Syringa vulgaris L.[38]	36	Oleaceae	Tree	Europe
***Thuja occidentalis* L.**	**34**	**Cupressaceae**	**Tree**	**E. US**
Syringa pubescens Turcz.[37]	33	Oleaceae	Shrub	Asia
Malus sp. (crabapple)[21]	32	Rosaceae	Tree	Unknown
Rosa sp.[30]	31	Rosaceae	Shrub	Unknown
Taxus xmedia Rehder[39]	31	Taxaceae	Shrub	Eurasia
Acer platanoides L.	30	Sapindaceae	Tree	Europe
Rhododendron 'P.J.M.'[29]	28	Ericaceae	Shrub	Asia
Hibiscus syriacus L.	27	Malvaceae	Shrub	Asia
Juniperus chinensis L.	27	Cupressaceae	Shrub	Asia
Weigela florida (Bunge) A. DC.	27	Caprifoliaceae	Shrub	Asia
Paeonia sp.[24]	25	Paeoniaceae	Herb	Eurasia
Picea abies (L.) H. Karst.	25	Pinaceae	Tree	Europe
***Picea glauca* (Moench) Voss[28]**	**25**	**Pinaceae**	**Tree**	**E. US**

Property characteristic data failed the Anderson-Darling tests for normality, thus Spearman-rank correlations were performed. Correlations were determined between taxa richness and the following property characteristics: property mortgage (US Dollars), property size (log acreage), and property age (years since construction). Correlations were analyzed using Minitab version 17.0 (Minitab 17 Statistical Software 2010). Ordinations were performed in PC-ORD 5.0 and have been shown to be an effective method for analyzing multivariate community structure (McCune & Grace, 2002). Taxa were not included within the ordination if they were found at less than 10% of all properties to account for the high level of absence data and to reduce ordination stress.

3. Results

We identified 356 distinct taxa across 101 total gardens sampled, of which 344 had discernible origins (Appendix A). Of the 25 most planted taxa across all garden properties, at least 21 originated from regions outside of the Eastern United States and only two species were considered native (Table 1). These species were Eastern white-cedar (*Thuja occidentalis*) and white spruce (*Picea glauca*) and were found at 34 (33.6%) and 25 (24.7%) of 101 properties, respectively. Most of the individuals of *Picea glauca* were found planted as the cultivated variety 'Conica'. The most abundant exotic taxon was daylily (*Hemerocallis* sp.). Rank curves indicated that the most abundant native plants were found at an approximately two-fold rate lower than the most abundant exotic plants (Fig. 1).

Exotics consistently represented more of the total richness as well as relative abundance in gardens, with 209 exotic taxa representing approximately 72% of total abundance compared to 135 native species representing approximately 28% of total abundance (Table 2). While native plant species were present and readily planted within gardens,

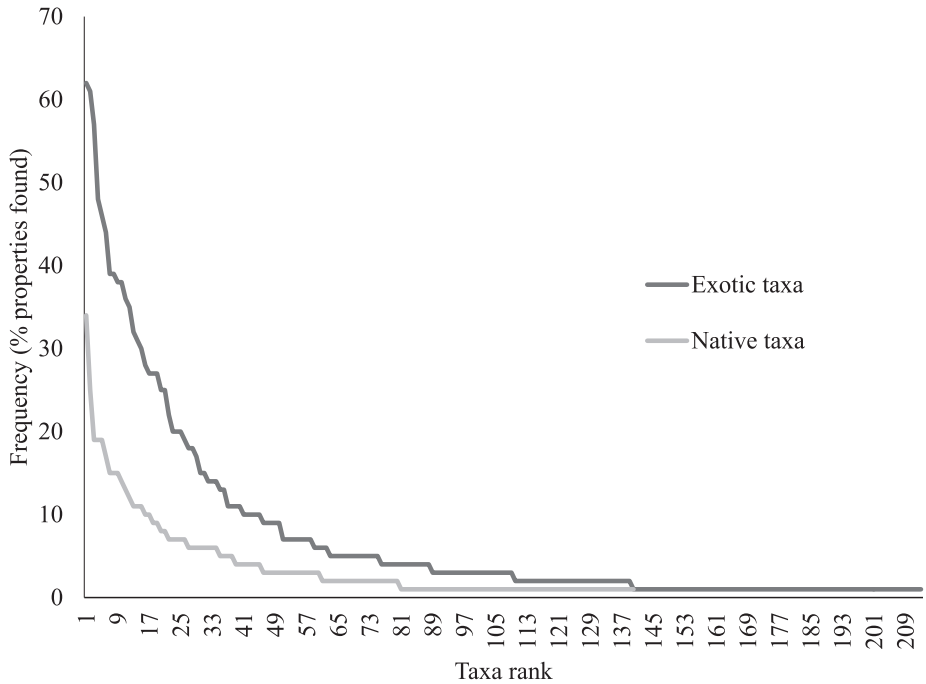

Fig. 1. Rank curve for plant taxa of exotic and native origin across 101 suburban gardens in Rochester, NY. Frequency (% properties found) represents the total % of properties taxa was planted out of 101 total properties. Rank one refers to the most planted species for both native and exotic taxa.

Table 2
Taxa richness (non-bolded numbers) and frequency of occurrence (bolded numbers) of plant growth type according to region of origin. Frequency of occurrence refers to the number of times plants of any taxa in that category were present in gardens. Study-wide percentages for richness and frequency by origin are indicated. This table only includes taxa for which an origin could be determined. E. US refers to Eastern United States and W. US refers to Western United States. Other includes Central and South America, Africa and Oceania.

	E. US (Native)	Asia	Eurasia	Europe	W. US	Other
Fern	4 **(23)**	1 **(4)**	–	–	–	–
Graminoid	5 **(9)**	4 **(49)**	3 **(4)**	1 **(5)**	–	–
Vine	5 **(7)**	7 **(38)**	2 **(21)**	2 **(9)**	–	–
Shrub	28 **(119)**	29 **(451)**	18 **(112)**	1 **(2)**	–	–
Herb	46 **(164)**	21 **(144)**	42 **(244)**	22 **(67)**	6 **(19)**	8 **(20)**
Tree	48 **(272)**	17 **(169)**	8 **(22)**	11 **(117)**	4 **(53)**	1 **(1)**
Total	136 **(594)**	79 **(855)**	73 **(403)**	37 **(200)**	10 **(72)**	9 **(21)**
Study-wide (%)	38% **(28%)**	22% **(40%)**	21% **(19%)**	11% **(9%)**	3% **(3%)**	3% **(1%)**

they were utilized to a lesser extent than exotics. For instance, exotic shrubs were planted approximately five times more than native shrubs; exotic herbs were planted approximately three times more than native herbs; and native trees were planted at an almost equivalent rate with exotic trees, representing only slightly more than half of the total planted material (Table 2).

On a finer scale, 24% of the taxa that were declared native to the Eastern United States were not considered truly native to New York State (Weldy et al., 2018). Of all taxa considered truly non-native to New York State, approximately 44% have been reported to naturalize (n = 91) (Weldy et al., 2018). While some of the 91 Naturalized (NAT) taxa were considered adventive from Mid-Atlantic, Midwestern or Southeastern US regions (e.g. *Campsis radicans*, *Chionanthus virginicus*), approximately 85% originate from either the W. US or other continents.

Property size was positively correlated with taxa richness ($r_s = 0.424$, $P < 0.0001$). Mortgage value was also positively correlated with taxa richness ($r_s = 0.417$, $P < 0.0001$). Relationships between taxa and mortgage amount and taxa and property size remained significant after removal of the mobile home properties ($r_s = 0.253$, $P = 0.028$; and $r_s = 0.274$, $P = 0.017$, respectively). There was a trend towards significance between taxa richness and age of property ($r_s = 0.379$, $P = 0.096$). NMDS ordination did not provide clear results in separating garden floristic structure according to socioeconomic standing (Appendix D).

4. Discussion

4.1. Exotic preference

This study indicates that ornamental suburban gardens surrounding Rochester, NY consist of predominantly exotic flora, with approximately 62% of taxa considered non-native to the Eastern United States with broad range classification. On a finer scale, 70% of taxa were considered truly non-native to New York State (Weldy et al., 2018). This means although certain species may be classified as native at local nurseries (e.g. *Echinacea purpurea*, *Hydrangea quercifolia*, *Chionanthus virginicus*), this may be outside of their true native range. Both current and future naturalization of exotic or adventive flora is likely due to high incidence of occurrence and thus high propagule pressure in surrounding natural areas. In the UK, higher market frequency and resulting propagule pressure has been shown to be a significant predictor of non-native garden plant escape (Dehnen-Schmutz, Touza, Perrings, & Williamson, 2007).

Of the exotics that were planted most regularly, certain species are known to naturalize throughout their planted range (i.e. *Syringa vulgaris*, *Spiraea japonica*, *Pyrus calleryana*), and some become truly invasive (e.g. *Acer platanoides*, *Berberis thunbergii*, *Euonymus alatus*, *Ligustrum* sp.). Native species such as *Acer saccharum*, *Cornus florida,* and *Hydrangea arborescens* were consistently planted less than their exotic congeners (*Acer palmatum*, *Cornus kousa*, *Hydrangea macrophylla*). While these exotic congeners have the potential to replace native species in gardens from an aesthetic standpoint, they likely fail to

replace them in trophic systems from an ecological perspective (Burghardt, Tallamy, & Shriver, 2009). While we did not quantify the gardening motivations behind homeowners in our study, our findings suggest similar results to a previous study that demonstrated the potential for aesthetic motivations to outweigh the perceived benefit of using native plants (Clayton, 2007).

4.2. Garden diversity and socioeconomic factors

As we expected, larger properties showed higher taxa richness. Smith et al. (2006) demonstrated this phenomenon in The United Kingdom, showing that a doubling of garden size increased the average number of species by 24.9%. Our data supported, in part, previous findings which have reported a "luxury effect" and "ecology of prestige" in which greater levels of garden diversity and vegetation cover is predicted by wealth, lifestyle behavior, and cultural norms (Hope et al., 2003; Marco et al., 2008). This; however, was not always consistent across mortgage groups. Although avid gardeners (properties with more than 40 taxa per garden) were not common, they were found across all socioeconomic groupings. Property age has also been found to be an important indicator of garden richness in urban areas (Hope et al., 2003); however, our findings only approached significance. This may have been attributable to our design which initially chose sample gardens at random and did not select based upon property age. Generally, it is expected that older properties acquire more species over time unless the property has undergone multiple ownership. It is not uncommon for new homeowners of older properties to remove established plant material and, instead, plant a more depauperate flora.

Of the 344 identified taxa, 66 were growing at a proportion of 10% or more of all gardens sampled, suggesting that a suite of taxa was especially popular across all socioeconomic groups. It is unclear if this was primarily due to underlying consumer choice, source limitation, or preference by landscape professionals. One homeowner physically presented their property base map (with plant materials) upon sampling; however, it is unknown what proportion of total gardens underwent prior professional design by landscape architects. It has been shown that gardens designed by landscape architects can be constrained by budget, stakeholder, and time, thereby controlling plant diversity at the garden level (Hooper, Endter-Wada, & Johnson, 2008).

In contrast to the utilitarian phenomenon noticed by Bigirimana et al. (2012), in which lower income households disproportionately planted more food plants compared to ornamental plants, we did not see a concerted effort across any household group to plant food species. It is unclear if this difference stems primarily from cultural, financial, social, or other reasons. One study performed in the city of Chicago indicated a high level of household vegetable gardens; however, this study relied heavily on aerial imagery without ground-truthing for residential gardens (Taylor & Lovell, 2012). Although our study area did not indicate many vegetable gardens at the level of the individual household, a high concentration of non-residential community gardens that grow at least some vegetables has been indicated for New York State (Lawson & Drake, 2013).

4.3. Influencing positive change

It has been clearly documented that naturalization and invasion of exotic garden plants increases over time due to increased availability at nurseries and propagule pressure (Lockwood, Cassey, & Blackburn, 2005; Pemberton & Liu, 2009). Due to the ready availability of exotic invasive plants at nurseries, legislation is sometimes a necessary means of regulating their spread. Additionally, concern regarding loopholes around legislation has been expressed through the marketing of less fecund cultivars as being "safe to natural areas", due to the potential for less fecund cultivars to still provide an invasive threat (Knight, Havens, & Vitt, 2011). Further loopholes around invasive legislation include internet trade, where websites such as eBay.com have shown to distribute significant supplies of invasive species to global consumers (Humair, Humair, Kuhn, & Kueffer, 2015). Therefore, it is crucial that legislation targets the initial suppliers of invasive plant material. If nursery owners continue to stock nurseries with an abundance of exotic plants, it will not be surprising to see this reflected in the surrounding garden flora.

Establishing voluntary codes of conduct within the nursery industry has shown to be an effective tool in theory, but difficult to implement across multiple stakeholders (Reichard, 2004). Furthermore, next to legislation, compliance and compatibility by nursery owners and gardeners has shown to consistently result from voluntary measures and educational outreach (Bell et al., 2003; Burt et al., 2007; Cronin, Kaplan, Gaertner, Irlich, & Hoffman, 2017; Reichard, 2004). Nursery owners can feel a lack of inclusion into regulatory processes (Cronin et al., 2017), and some homeowners may prefer to be educated on which species are invasive instead of told verbatim what they cannot grow in their own gardens.

A major difficulty in controlling garden use is the myriad of factors that determine garden diversity and design such as aesthetics, homeowner attitudes, economic factors, and even the desire to meet neighborhood standards (Clayton, 2007; Dehnen-Schmutz et al., 2007; Kendal, Williams, & Williams, 2012). One survey of Landscape Architects revealed that the biggest perceived limitation to native plant use was customer receptivity and failure of market supply to keep up with demand (Hooper et al., 2008). While we observed limited supply of abundant natives in local nurseries, personal communication with homeowners during the course of this study revealed receptivity to natives. While most homeowners failed to identify the invasive species within their gardens, they often expressed a willingness to remove these species and, in place of, plant natives. Some homeowners even requested suggestions on native alternatives, demonstrating that personal interactions have the potential to directly alter homeowner perceptions. Previous findings have revealed increased support for invasive management after increasing public awareness (Novoa, Dehnen-Schmutz, Fried, & Vimercati, 2017). We suggest encouragement of native plant usage instead of merely prohibiting nefarious invasive species, which could be directly communicated at the interface of consumers with nursery workers and landscape professionals. Better connectivity should also be encouraged between landscape professionals and regional ecologists. Legislation, education, volunteer initiatives, and outreach are all forces that can concomitantly affect positive change within the horticultural industry.

Future garden inventories in the Northeastern US may reveal clearer patterns related to exotic-abundance, drivers of garden diversity, and underlying causes to garden assemblages; especially if properties are preferentially chosen based upon socioeconomic factors. Research may benefit from aerial-image analyses that seek to investigate land-cover use efficiency in suburban landscapes. Further research related to exotic invasive plants in gardens should explore opportunities to expand inclusive legislation, improve volunteer initiatives by nursery and landscape professionals, address landscape-level invasive management, and enhance educational outreach to the gardening public.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.landurbplan.2018.09.004.

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