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RESEARCH ARTICLE

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# Does Suburban Horticulture Influence Plant Invasions in a Remnant Natural Area?

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**ABSTRACT**: The horticultural trade is a well-known source of nonnative invasive plant species, yet urban and suburban developments are routinely planted with these species, creating high invasion pressure on adjacent natural areas. Understanding the spread of nonnative species and predicting invasions is critical for the management of natural habitats. Here, we examine the similarities in nonnative plant community composition between a remnant natural habitat at Fire Island National Seashore and the surrounding residential communities to assess the impact of nonnative invasive horticultural species on the natural area. In the natural area, we identified 16 locally listed invasive plant species. In residential areas we identified 21 locally listed invasive species. Of 162 properties surveyed, 144 appeared to be occupied and maintained by residents; 18 appeared unmaintained or abandoned. Unmaintained properties had significantly more invasive species than maintained properties. Nonnative species composition between the natural and residential areas was not significantly different. In the natural area, distance from suburban edge, native species richness, and soil moisture were important drivers of invasion. We show that in this particular natural area, invasive plants have not invaded farther than 25 m into the forest, indicating the strong role of edge effects in invasions. Additionally, we show that unmaintained properties in the residential areas may be the primary source of invasives to natural area. Homeowner education on the impacts of invasive species and active management of the nonnative invasive species in the unmaintained properties may be important for preventing further invasions to the forest.

*Index terms:* edge effects, Fire Island National Seashore, homogenization, invasive plants, wildland–urban interface

## INTRODUCTION

Nonnative invasive plant species may disrupt the ecological services of native ecosystems (Gordon 1998; Dukes and Mooney 2004), change the composition of native habitats (Hejda et al. 2009), and cause declines in populations of native species (Clavero and Garcia-Berthou 2005). Nonnative invasive species also represent an economic threat with estimated losses of up to 120 billion USD per year, of which nonnative invasive plants account for 25 billion USD (Pimentel et al. 2005). As the number of plant species introduced accidentally or deliberately via horticulture increases, the rate of invasions is also expected to increase (Westbrooks 2004; Gavier-Pizarro et al. 2010). As a result, it is predicted that biodiversity in communities currently dominated by native species will decrease as they become invaded by a few globally common nonnative species (Rooney et al. 2004; McKinney 2006). This process of biotic homogenization, or the simplification of biota via species introduction, threatens the natural history identity of wild protected areas (National Park Service 2010).

Invasions of nonnative plants are closely tied to human activities at global, regional, and local scales. The global horticultural trade is well known to be the primary source of invasive plant species introductions (Reichard 1997; Reichard and White 2001), particularly for ornamental species (La Sorte et al. 2014). Anthropogenic landscape change, including human development and fragmentation of natural habitats at the regional scale, is tied to invasions in a variety of ways including facilitating dispersal and establishment via roads, edge habitats, and changes in stream hydrology (von der Lippe and Kowarik 2008; Gavier-Pizarro et al. 2010). Urbanization, in particular, causes the decline of native species concurrent with the establishment of nonnative species (e.g., McKinney 2006; Aronson et al. 2015). At the local scale, management decisions by homeowners influence species composition, often in favor of nonnative ornamental species (Cubino et al. 2015).

Natural areas in urban and suburban landscapes are at high risk for invasion by the many nonnative species continually introduced in the yards and gardens of the adjacent residential neighborhood (Stewart et al. 2007; Hanspach et al. 2008; Cubino et al. 2015). Suburban developments are routinely planted with a variety of both native and nonnative ornamental species and this invasion risk is expected to increase with increasing horticultural introductions and climate change (Westbrooks 2004). Nonnative plant species are planted in high abundances in residential developments, thus there could be high propagule pressure of these species on adjacent natural areas. Most research on wildland–urban interfaces has focused on wildfire risks (see Radeloff et al. 2005), however the way that human settlements affect neighboring ecosystems through invasive species introduction warrants further examination. The influences of urban and suburban settlements on natural areas range from obvious destruction and fragmentation of habitats to the less easily observed results of these processes, such as increased propagule pressure of invasive species and edge effects (Bar-Massada et al. 2014).

In the United States, there are approximately 4000 nonnative plant species that have spontaneously established in natural habitats. Of these, one-fourth are considered threats to native plant and animal communities (Sullivan et al. 2005; National Park Service 2010). Examples of such plant species in the northeastern United States include Japanese barberry (*Berberis thunbergii* DC.), Oriental bittersweet (*Celastrus orbiculatus* Thunb.), and Japanese honeysuckle (*Lonicera japonica* Thunb.). In the New York metropolitan area, plant invasions by these species cause the decline of native species biodiversity and are actively managed by many natural areas land managers. However, these and other known invasive plants continue to be sold in local and national nurseries (Burt et al. 2007). Here, we examine the influence of invasive horticultural plantings and spontaneous invasive populations in suburban housing developments on the structure of plant invasions in the natural areas of the William Floyd Estate, Mastic Beach, New York. We hypothesized that suburban plants are important sources of invasions to natural areas. Understanding the role of yard floras on plant invasions in natural areas will provide a basis for suburban garden management practices that incorporate native plant biodiversity.

## METHODS

### Study Area

The William Floyd Estate (WFE), 40°46′N, 72°49′W, is part of the Fire Island National Seashore located on Long Island in Mastic Beach, New York, USA (Figure 1). The WFE lies within a newly recognized biodiversity hotspot, the North American Coastal Plain (Noss et al. 2015; CEPF 2016). The town of Mastic Beach has a population of 7464 people. The estate is surrounded on three sides by moderately dense suburban housing (~375 single family houses/$km^2$) and serves as a refugium for diverse plant and wildlife species. The northern long-eared bat or northern myotis (*Myotis septentrionalis* Troue.), a federally threatened species, can be found at the WFE. Additionally, a pair of bald eagles (*Haliaeetus leucocephalus* L.) has nested within the boundaries of the reserve since 2014. The WFE is the former plantation and home of William Floyd, one of the original signers of the US Constitution. The WFE has been part of Fire Island National Seashore since 1965 and includes 248 ha of secondary forest, some of which was never farmed. The forested areas are dominated by coastal oak–heath forest and by pitch pine–oak forest, maritime deciduous scrub forest, and acidic red maple basin swamp forest (red maple–black gum dominant) (Klopfer et al. 2002). The surveyed areas in this study were primarily within the pitch pine–oak forest type, which is approximately 80–100 y old and is managed as a natural area currently by the US National Park Service. This community is dominated by native species composed of a canopy including *Quercus alba* L., *Quercus rubra* L., *Carya* spp., *Sassafras albidum* Nutt., *Prunus serotina* Ehrh., and *Acer rubrum* L., with *Pinus rigida* Mill. interspersed intermittently (Clark 1986). The shrub layer is dominated by *Gaylussacia baccata* Wangenh., except for a few low-lying wet areas dominated by *Clethra alnifolia* L. While the forested areas are primarily dominated by native species, there is high risk of further invasion by existing and new horticultural species introductions in the bordering residential neighborhoods.

### Natural Area Surveys

We established nine 100-m transects in forested areas in the north and west regions of the WFE. We established six 5 × 5-m plots along each transect (Figure 1) for a total of 54 plots. Within each plot, we identified all native and nonnative trees, shrubs, and ground vegetation and measured soil pH, soil moisture, canopy cover, and light availability. We estimated percent cover of each nonnative species present in the plot as well as estimating total percent cover of all native plant species in the plot (combined) and percent cover of the dominant understory native species. We also identified canopy species present in or overhanging the plots.

We measured soil pH with a FieldScout pH 110 meter (Spectrum Technologies, Plainfield, IL) at four random locations within each plot. To measure soil pH, we scraped aside leaf litter and sampled soil to 5-cm depth. We used equal parts soil and distilled water to create a slurry and measured the pH of the slurry. We also measured soil moisture with a FieldScout TDR 100 soil moisture meter (Spectrum Technologies) at four random locations within each plot. We measured light availability in the understory at the center and two random locations within each plot using a LI-COR light meter and line quantum sensor (LI-COR 250A and 191SA; LI-COR Biosciences, Lincoln, NE). We collected all light availability data on the same uniformly sunny day between 10:00 AM and 2:00 PM.

### Residential Area Surveys

We conducted residential vegetation surveys also during June 2014 in neighborhoods on streets immediately surrounding the WFE, running along the same compass bearing as the transects within the natural area. We visually identified the presence of targeted invasive nonnative species in residential front and side yards on both sides of the street occurring within 300 m of the border of the estate (Figure 1). Targeted invasive nonnative species were defined from two sources: (1) those nonnative invasive species found in the natural area surveys, and (2) nonnative invasive species listed by the Long Island Invasive Species Management Area (LIISMA). LIISMA is a partnership of government agencies, nonprofit organizations, and private businesses and coordinates invasive species management and education


**Figure 1. Location of natural area surveys within and residential area surveys surrounding the William Floyd Estate (WFE), Mastic Beach, New York.**

across the region (LIISMA 2016). In 2008, LIISMA designed a protocol for assessing the invasiveness of nonnative plant species found in the region (LIISMA 2016). The protocol ranks nonnative plant species invasive threat levels from Low to Very High. These rankings are based on several criteria, including ecological impact, biological characteristics, dispersal ability, ecological amplitude, distribution, difficulty to control, and status of cultivars/hybrids.

### Data Analyses

We compared the community composition (presence/absence) of all nonnative species found in the natural area and the residential area (24 species) using nonmetric multidimensional scaling (NMDS) and multiple response permutation procedure (MRPP). We used *t* tests to assess the difference in nonnative invasive species richness between the occupied and unoccupied residential units (JMP Pro 11.2.0; SAS Institute, Cary, NC). We used stepwise multiple linear regression to assess the relationship between the richness and cover of nonnative species and local environmental variables (distance from edge in meters, soil pH, soil moisture, light availability, native plant cover) within the WFE (JMP Pro 11.2.0).

## RESULTS

### Natural Area and Residential Surveys

We found 46 native, 15 targeted LIISMA-listed nonnative invasive, and 4 nonnative plant species not listed present in the natural area (Table 1, Appendix 1). In all but four transects, nonnative species did not penetrate more than 5 m into the forest from the fence line delineating the edge of the estate. In all transects, nonnative species did not penetrate more than 25 m from the estate's edge. The three most frequently occurring nonnative species in plots within the WFE were *Lonicera japonica* (occurring in 20.4% of plots), *Rosa multiflora* Thunb. (occurring in 13.0% of plots), and *Celastrus orbiculatus* (occurring in 7.4% of plots). All three of these species are ranked by LIISMA as "very high" priority nonnative invasive plant species.

In residential areas, we identified 24 LIISMA-listed nonnative invasive plant species (Table 1). Of 162 properties surveyed, 144 appeared to be currently occupied and maintained by residents (as determined by evident landscaping maintenance, presence of vehicles, and/or visible occupants) while 18 appeared unmaintained or abandoned (as determined by lack of evident landscaping maintenance, boarded windows, confirmation from neighbors, and/or were vacant lots). On average, occupied properties contained 2.13±0.49 nonnative invasive LIISMA listed species. Unmaintained areas contained significantly more nonnative invasive species than maintained properties, with an average of 5.89±0.16 nonnative species per property ($t = 7.85$, $P < 0.01$).

The three most frequently occurring LIISMA-listed nonnative species in surveyed residential areas were *Acer platanoides* L. (occurring in 31.7% of surveyed properties), *Artemisia vulgaris* L. (occurring in 31.1% of surveyed properties), and *C. orbiculatus* (occurring in 29.2% of surveyed properties). *Acer platanoides* and *C. orbiculatus* are ranked by LIISMA as "very high" priority species and *A. vulgaris* is ranked as "high" priority.

Nonnative invasive species composition was similar between the natural area and the neighborhoods (Figure 2). There was no separation of the natural area from the residential nonnative plant communities in NMDS ordination space (Axis 1: $F = 0.6121$, $P = 0.4462$; Axis 2: $F = 1.6751$, $P = 0.2152$). However, the residential communities were clustered closer in ordination space, indicating less variation among residential plant communities than in the natural communities. Residential nonnative plant communities had significantly lower beta diversity (average Sorensen's distance = 0.24) than the natural area (average Sorensen's distance = 0.69; MRPP, $A = 0.18$, $P < 0.0001$).

**Table 1. Nonnative invasive plant species found in the natural areas and residential areas and their invasive rank as assessed by Long Island Invasive Species Management Area (LIISMA). VH = very high invasiveness; H = high invasiveness; M = moderate invasiveness; L = low invasiveness; NR = not rated.**

| Species | Residential | Natural Area | LIISMA rank |
|---|---|---|---|
| *Acer palmatum* | x | x | M |
| *Acer platanoides* | x | x | VH |
| *Albizia julibrissin* | x | x | VH |
| *Alliaria petiolata* | x | | L |
| *Ampelopsis brevipedunculata* | x | | H |
| *Aralia elata* | x | x | VH |
| *Artemisia vulgaris* | x | x | H |
| *Berberis thunbergii* | x | x | VH |
| *Celastrus orbiculatus* | x | x | VH |
| *Cornus kousa* | x | x | NR |
| *Elaeagnus umbellata* | x | x | VH |
| *Epipactis helleborine* | x | x | NR |
| *Euonymus alatus* | x | | VH |
| *Hedera helix* | x | | M |
| *Ligustrum vulgare* | x | | H |
| *Lonicera japonica* | x | x | VH |
| *Morus alba* | x | | M |
| *Phragmites australis* | x | x | VH |
| *Phyllostachys* spp. | x | | NR |
| *Robinia pseudoacacia* | x | x | VH |
| *Rosa multiflora* | x | x | VH |
| *Rubus phoenicolasius* | x | | VH |
| *Solanum dulcamara* | x | | M |
| *Wisteria* spp. | x | x | M |

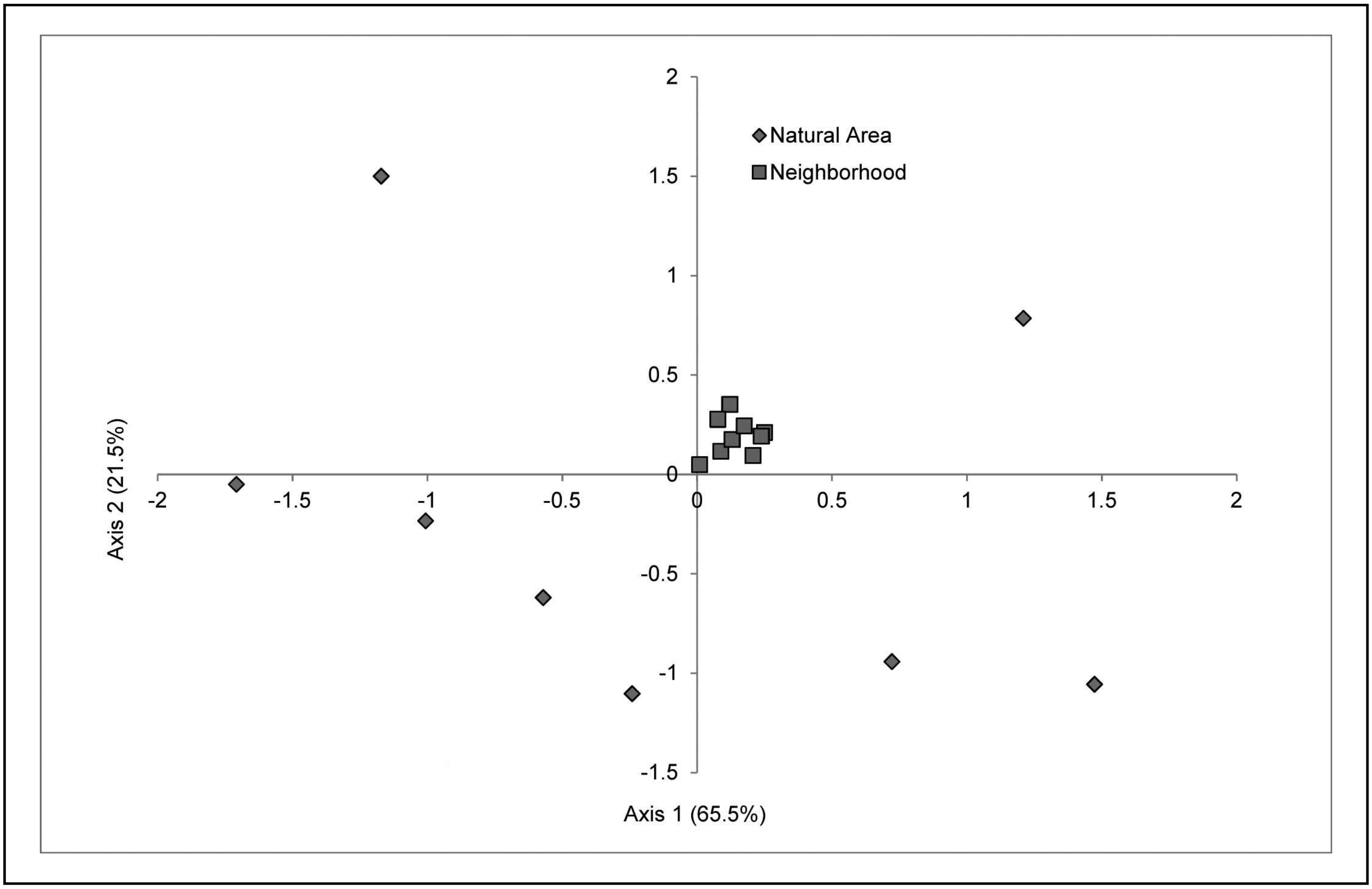


**Figure 2. Nonmetric multidimensional scaling (NMDS) of nonnative invasive species composition between the natural areas (diamonds) and the neighborhoods (squares), William Floyd Estate, Mastic Beach, New York.**

## Drivers of Invasion

We performed multiple regression to assess the most important drivers of invasion within WFE. For the number of invasive species in each natural area plot, distance from suburban edge and native richness were significant drivers ($R^2$ = 0.38, $P >$ 0.0001) with plots closer to the forest edge ($P < 0.0001$) and plots with fewer natives being more highly invaded ($P$ = 0.10), although not significant. Soil moisture, soil pH, light availability, and the percent cover of native species were not significantly related to the number of invasive species in the natural area plots. Distance from the suburban edge ($P$ = 0.003) and soil moisture ($P$ = 0.10) were found to be important drivers of the percent cover of invasive plant species in the natural area ($R^2$ = 0.18, $P$ = 0.007). There was more invasive cover closer to the suburban edge and decreased invasive species cover with increasing soil moisture.

## CONCLUSIONS

Urban and suburban areas are often considered the epicenters of plant invasions, yet the processes that structure plant invasions in urban areas are not well understood (Gaertner et al. 2017). Here we found that the most common nonnative invasive species in the residential communities were also the most common in the natural area. This result supports a growing body of evidence that invasive species planted in residential areas are sources for invasions to nearby natural areas (Sullivan et al. 2005; Alston and Richardson 2006; Hanspach et al. 2008; Gavier-Pizarro et al. 2010; Bar-Massada et al. 2014; Cubino et al. 2015). This propagule pressure may stem from horticultural plantings done purposefully by homeowners; however, in this case, abandoned and unmaintained properties in residential areas also seem to serve as a reservoir for the invasive species found in the WFE natural area. Additionally, our results support other research on the importance of edge effects for facilitating plant invasions; here, distance from edge was a significant driver of invasion at the local scale.

The reduction of the size of natural areas and the subsequent increase in the proportion of edge habitats is a particularly widespread human-induced environmental change. Proximity to forest edge has been shown to be a predictor of invasion across many forest ecosystems (Brothers and Spingarn 1992; Honnay et al. 2002; Foxcroft et al. 2010). Forest edges are commonly drier (Chen et al. 1993), sunnier (Matlack 1993), subject to higher temperature fluctuations (Kremsater and Bunnell 1999), and experience higher levels of deer herbivory (Alverson et al. 1988) than interior habitats. All of these characteristics can lower the habitat quality for native plant species, making these edges more susceptible to invasion by nonnative invasive species. Nonnative invasive plants often have life history traits that allow them to colonize habitats that many native plants cannot tolerate. The top three most frequently occurring nonnative species in edge plots in the WFE have all been shown to be particularly tolerant to edge effects (Keane and Crawley 2002; Ashton and Lerdau 2008; Rawinski 2008).

In this system, high native richness may be an indicator of resistance to invasions. Two mechanisms may be responsible for this observation. First, our results are consistent with other literature in the field showing that increased native biodiversity confers resistance to invasion. High native richness interferes with the establishment and success of nonnatives (Knops et al. 1999; Kennedy et al. 2002; Hooper et al. 2005) by increasing competition and crowding and by decreasing available light and soil nutrients (Naeem et al. 2000), thus preventing nonnatives from becoming overly dominant in communities with high native biodiversity. Second, in general, pineland forests, such as the one studied here, are resistant to invasions (Howard et al. 2004; Gurevitch et al. 2008) due to low soil fertility and reduced light availability (Gurevitch et al. 2008). However, when soil nutrients are increased, in particular nitrogen and calcium, invasion resistance is decreased in these pineland forests (Gurevitch et al. 2008). Human activities in the suburban landscape, such as applying lawn fertilizers, may result in increased soil nutrients at the forest edge, reducing the resistance conferred by low soil fertility.

At the neighborhood scale, nonnative invasive species richness did not significantly differ from richness within the WFE. There is evidence that propagule pressure from neighborhoods is a strong factor in the spread of nonnatives into natural areas (Sullivan et al. 2005; Alston and Richardson 2006). The higher the frequency at which a species is planted in neighborhood gardens, the more likely it is to be found in surrounding natural areas (Marco et al. 2010) and, in fact, the edges of natural areas often serve as a filter for nonnative propagules, with nonnative species being unable to penetrate more than a few meters past the highly invaded boundaries of natural areas during the first stages of invasion spread (Foxcroft et al. 2010), a result we found consistent with our study.

The neighborhoods surrounding the WFE contain many areas that are not subjected to regular maintenance. Some of these properties were abandoned or repossessed and some were areas between property lines that owners from neither side maintained. These areas had significantly higher nonnative invasive species richness as compared to properties that were occupied and underwent regular yard maintenance. These properties may provide a reservoir for nonnative propagules that can potentially spread to natural areas like the WFE. In our study, unmaintained areas were particularly dominated by *L. japonica* and *R. multiflora*, some of the most frequently occurring invasive plants within the WFE. This phenomenon has been documented in urban Poland, where *Fallopia* spp. were found in increased abundance in unmaintained areas (Soltysiak and Brej 2014). In towns and cities, vacant lots are ubiquitous across the landscape, and our work highlights the importance of managing these areas in addition to maintaining private yards and gardens to reduce the threat of invasions to adjacent natural areas.

While nonnative invasive species composition overlapped among residential lots and natural area plots, beta diversity was much lower across residential lots. In particular, we found less variation in species composition among invasive plant communities in residential lots, including abandoned and unmaintained lots, than those nonnative plant communities in the natural area. This points to the difference in processes that structure nonnative plant communities in residential areas vs. natural areas. As we have shown here, distance to edge, native species richness, and soil moisture were the most important determinants of invasive species composition in the natural area. In residential lots, human influences are the most important driver of nonnative species composition. Social pressures and aesthetics often drive management goals and plant species composition in yards and gardens (Nassauer et al. 2009; Cook et al. 2012) such that residents often mimic their neighbors in management decisions and species composition of their yards and gardens (Minor et al. 2016). The small variation in species composition among residential lots in this study points to homogenization of species composition in yards driven by human decision-making (Groffman et al. 2014).

## Management Implications

Very few natural areas remain in the northeastern United States due to the high population density of the area, and those that do remain are often surrounded by urban or suburban developments. These areas are of particular conservation value in the region. Our work indicates that sources of both planted and spontaneous nonnative invasive populations from surrounding urban and suburban development can contribute to the spread of invasives into natural areas. We propose two strategies that can address this. First, prevention in the form of public education on the impacts of horticultural invasions and second, management, in the form of invasive plant removal in private yards and gardens, vacant lots, and other unmaintained properties.

Prevention and management of nonnative invasive plant species lays not just in identifying probable invaders and rapidly responding to these invasions, but also in heightening public awareness. In general, public awareness of invasive plant species begins only after a species has invaded an area. Educating the general public early, before a known invasive species establishes in a new area, will likely decrease the abundance of these species in gardens and, therefore, decrease the likelihood that a species will escape to adjacent natural areas. Public education is necessary to prevent invasions by reducing the purchase of horticulturally popular species in neighborhood areas. After education regarding the threats of nonnative invasive plants, property owners are less likely to purchase these plants for use in their yards and gardens (Reichard and White 2001). Educational outreach can be coupled with regulation of nurseries to both reduce nonnative sales and increase the use of native plants in landscape design. Increased collaboration between nursery owners, homeowners, and ecologists will provide a scientific basis for bans on the sale of nonnative plants, particularly those shown to demonstrate high invasiveness (Gagliardi and Brand 2007; Marco et al. 2010).

In addition to educating the public and regulating sales of nonnative invasive species, municipalities must prioritize invasive plant management in unmaintained properties within neighborhoods as they pose a significant threat to natural areas. Maintenance of areas between property lines should fall under the responsibility of the municipality, however implementation and upkeep of management will require considerable work. Property owners should be encouraged to remove invasive nonnative plants from their yards and gardens.

In this study, we utilized the Long Island Invasive Species Management Area's *Non-native Plant Species Invasiveness Assessment* (LIISMA 2016) to choose species to survey in both the natural and the residential communities. Using regional and state-wide assessments, such as this one, is useful in identifying possible invaders. Utilizing these lists to prioritize high-risk invaders for prevention and adaptive management can help focus management plans for early detection and rapid response. In natural areas, particularly at habitat edges, monitoring for species that are known invaders in the region is imperative for maintaining healthy and resilient native ecological communities at the wildland–urban interface.

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**Appendix. All species found in natural areas at the William Floyd Estate, Mastic Beach, New York. *Indicates plant species not native to the area.**

*Acer palmatum**
*Acer platanoides**
*Acer rubrum*
*Alliaria petiolata**
*Allium vineale**
*Amelanchier canadensis*
*Aralia elata**
*Aralia nudicaulis*
*Arisaema triphyllum*
*Aronia arbutifolia*
*Artemisia vulgaris**
*Berberis thunbergii**
*Carex* spp.
*Carya glabra*
*Carya tomentosa*
*Celastrus orbiculatus**
*Chimaphila maculata*
*Clethra alnifolia*
*Cornus kousa**
*Cypripedium acaule*
*Daucus carota**
*Dennsteadtia punctiloba*
*Elaeagnus umbellata**
*Epipactis helleborine**
*Forsythia* spp.*
*Fragaria vesca*
*Gaultheria procumbens*
*Gaylussacia baccata*
*Ilex* spp.
*Impatiens capensis*
*Lindera benzoin*
*Lonicera japonica**
*Maianthemum canadense*
*Maianthemum stellatum*
*Medeola virginiana*
*Melampyrum lineare*
*Monotropa uniflora*
*Nyssa sylvatica*
*Osmundastrum cinnamomeum*
*Oxalis stricta*
*Parthenocissus quinquefolia*
*Phragmites australis**
*Pinus rigida*
*Poaceae*
*Prunus serotina*
*Pteridium aquilinum*
*Quercus alba*
*Quercus rubra*
*Rhododendron viscosum*
*Robinia pseudoacacia**
*Rosa multiflora**
*Rubus* spp.
*Sassafras albidum*
*Smilax glauca*
*Smilax rotundifolia*
*Solidago* spp.
*Symplocarpus foetidus*
*Taraxacum officinale**
*Toxicodendron radicans*
*Vaccinium* spp.
*Verbena* spp.
*Viburnum acerifolium*
*Viburnum dentatum*
*Viola* spp.
*Vitis* spp.
*Wisteria* spp.*