12

Factors Influencing Non-Native Tree Species Distribution in Urban Landscapes

Wayne C. Zipperer

USDA Forest Service, Gainesville, FL, USA

Summary

Non-native species are presumed to be pervasive across the urban landscape. Yet, we actually know very little about their actual distribution. For this study, vegetation plot data from Syracuse, NY and Baltimore, MD were used to examine non-native tree species distribution in urban landscapes. Data were collected from remnant and emergent forest patches on upland sites and riparian habitats. Non-native tree species were divided into three groups based on their frequency of occurrence: ubiquitous, common and infrequent. Unique species distributions were observed. For example, *Acer platanoides* was a common species on remnant forest patches but was an ubiquitous species on emergent forest patches. In riparian habitats, however, *A. platanoides* was infrequent. Site histories also played an important role, especially for infrequent species on upland sites. For example, *Syringa vulgaris* occurred only on abandoned residential sites. Surprisingly, riparian habitats had only four non-native tree species as compared to seven for remnant and 23 species for emergent forest patches on upland sites. No ubiquitous, non-native tree species were observed for riparian habitats and only one species – *Morus alba* – was common. It occurred on 11 of the 33 plots. The other three non-native species on riparian sites occurred infrequently. For upland and riparian

Urban Biodiversity and Design, 1st edition.
Edited by N. Müller, P. Werner and John G. Kelcey.

forest patches, non-native tree species occurrence and prevalence were related overall to patch history and site disturbance.

Keywords

urban landscapes, site history, non-native species

Introduction

Invasive species only represent a small portion of non-native species in a region (Reichard & White, 2001). Yet, they receive a considerable amount of attention because of their effect on ecosystem structure and function (Mack *et al.*, 2000). Most existing research has been conducted on grassland ecosystems in rural landscapes and on non-woody species (Martin *et al.*, 2008). Information on the effects of non-native tree species in urban forest patches is needed.

In urban landscapes, non-native tree species can play a significant role in providing ecosystem services. Ecosystem services are those goods and benefits that humans derive from natural ecosystems (de Root *et al.*, 2002). For urban landscapes, these services include reduction of noise and air pollution, increased aesthetics, improved air and water quality, additional wildlife habitat, and improved property value (Nowak & Dwyer, 2000). Analysis of composition and structure of the urban forest in Syracuse, NY shows that non-native species represent 53% of the total number of species (68) inventoried and account for 45% of the total net carbon sequestered (3515.3 metric tons (mt)) (Table 12.1). Carbon sequestration varies by land use. Transportation and utility corridors contained the highest portion of non-native species (60%), whereas residential land use had the greatest portion of net carbon sequestered (56%) by non-native species. Although non-native species play a significant role in urban landscapes, we know relatively little about their actual distribution within the metropolitan area. Forest patches within the urban landscape offer an opportunity to address this deficiency.

Site history plays an important role in defining forest ecosystems in urban landscapes. There are two types of forest patches in the urban landscape: remnant and emergent (afforested) (Zipperer, 2002). Based on photographic records, remnant forest patches may have been cleared for urban use prior to the 1930s, but were in forest cover in 1938 (the earliest, comprehensive record of aerial photograph in the United States). In contrast, emergent forest patches developed on sites that were cleared for urban use and subsequently abandoned after 1938.

Table 12.1 Non-native tree species as a percentage of all trees and net carbon sequestered by land use[a] in Syracuse, NY (Nowak, per. com).

Land use	Number of species (% non-native)	Net carbon sequestered[b] (mt/ha/yr) (% non-native)
Commercial	3 (33)	189.4 (14)
Greenspace	30 (40)	488.5 (34)
Multi-family	15 (40)	138.3 (49)
Residential	49 (52)	1825.4 (56)
Transportation/utility	12 (60)	114.6 (40)
Vacant	30 (51)	474.6 (20)

[a]Commercial: businesses Greenspace: Forests and managed parklands Multi-family: More than two families living in a structure; e.g., apartment complexes Residential: single-detached housing. Often, one family per structure Transportation/utility: roads, canals, paths, and right-of-ways Vacancy: Abandoned urban site that is unmanaged

[b]The net amount of carbon taken up and stored by trees during a year

Forest patches in urban landscapes are unique because of their composition, the environmental context in which they occur, and their size. Compositionally, remnant forest patches are dominated by native species but also contain non-native species, whereas emergent forest patches are dominated by non-native species (Zipperer, 2002). Environmentally, these forests exist in an urban heat island which can affect biological and chemical processes (Carreiro & Tripler, 2005), and are exposed to atmospheric and edaphic conditions which may alter growth (McDonnell, 1988; Gregg *et al.*, 2003). Finally, the remaining forest patches often represent small fragments of the original forest (Zipperer *et al.*, 1990).

In this chapter, I used frequency of occurrence from emergent and remnant forest patches in Syracuse, NY (see Zipperer, 2002) and riparian habitat in Baltimore, MD to examine the distribution patterns of non-native tree species in upland and riparian forest patches in urban landscapes. A historical account of changes in species distribution was not possible because of insufficient data.

Methodology

In Syracuse, NY, 12 remnant and 23 emergent patches were inventoried. For patches ≥ 1 ha in size, 200 m^2-circular plots were used to inventory woody species whose diameter at breast height (DBH) were ≥2.5 cm DBH. The number of plots per patch was determined by the size of the patch. Patches < 1 ha in size were inventoried completely. For a more detailed description of sampling protocol, see Zipperer (2002).

Riparian habitats in this study were often represented by a linear-forest patch along a stream in Baltimore, MD. For each stream channel with forest cover, a series of transects were laid perpendicular to the stream at 50 m intervals. From these transects, a subset of transects was randomly selected for sampling. A series of 10 × 10 m plots were located on a transect starting at the stream bank and then every 30 m. The number of plots per transect varied by floodplain width. On each 100 m^2 plot, DBH and type of species for all woody stems ≥2.5 cm DBH were recorded.

Based on frequency of occurrence, each species was classified as ubiquitous, common or infrequent. Ubiquitous species occurred on more ≥75% of patches or plots (for riparian habitat) sampled. Common species occurred on 25–75% of the patches or plots sampled. Infrequent species occurred on ≤25% of the patches or plots sampled. For each species, a species-importance value was calculated to compare the relative contribution of the species to stand structure (Curtis & McIntosh, 1951). For the emergent and remnant forest patches, a species-importance value was calculated by summing relative density (density of a species as percentage of total density for all species) and relative basal area (basal area for a species as a percentage of total basal area) and dividing by 2. For riparian forest plots, species-importance values were calculated by summing relative density, relative basal area, and relative frequency (number of plots a species occurred as percentage of total number of plots) divided by 3.

Results

Emergent and remnant patches: Syracuse

The emergent upland forests had the greatest non-native species richness (23) followed by remnant upland forests (7) (Table 12.2). The frequency of non-native species occurrence, however, differed between emergent and remnant patches (Table 12.3). *Rhamnus cathartica* L. was the most ubiquitous species. It occurred in all the remnant patches and all but four emergent patches. *R. cathartica* is an invasive species that is dispersed by birds, and occurred in the smaller diameter size class (≥2.5–9.9 cm DBH) (Zipperer, 2002).

Table 12.2 **Number of native and non-native tree species sampled in remnant and emergent forest patches in Syracuse, NY and riparian habitat in Baltimore, MD.**

	Syracuse		Baltimore
	Remnant	Emergent	Riparian
Total number of species	42	62	35
Total number of non-native tree species	7	23	4

Table 12.3 **Frequency of occurrence and species-importance values of ubiquitous and common species on remnant and emergent forest patches in Syracuse, NY, and riparian habitats in Baltimore, MD.**

	Syracuse-Remnant	
	Frequency (%)	**Species importance**
Rhamnus cathartica	100	15.18[a]
Acer platanoides	50	5.94
Prunus avium	50	2.42
	Syracuse-Emergent	
Acer platanoides	87	29.47[a]
Rhamnus cathartica	83	3.54
Ailanthus altissima	43	3.39
Prunus avium	39	1.07
Lonicera spp.	26	0.32
	Baltimore-Riparian	
Morus alba	33%	13.24[b]

[a]IV=((relative density)+(relative basal area))/2
[b]IV=((relative density)+(relative basal area)+(relative frequency))/3

A. platanoides L. showed a different pattern. In the remnant patches, it was a common species occurring on 6 of 12 patches, but was a ubiquitous species on all 23 emergent patches (Table 12.3). *A. platanoides*, also an invasive species, is dispersed by wind. Unlike *R. cathartica*, *A. platanoides* was planted as a street tree. These street plantings served as seed sources. Because *A. platanoides* has a different growth form, it occupied a greater range of diameter classes in both the emergent and remnant forest than *R. cathartica* (Zipperer, 2002).

The other commonly occurring non-native species on remnant forest patches was *Prunus avium* L. (Table 12.2). Like *A. platanoides*, *P. avium* occurred on six patches but had a lower species-importance value than *A. platanoides*. By comparison, emergent forest patches had three common non-native species: *Ailanthus altissima* (Mill.) Swingle, *Lonicera* spp. and *P. avium*. A comparison of common species showed that *A. altissima* had the highest species-importance value and occurred more frequently than either *P. avium* or *Lonicera* spp. By far, most non-native species (18) were infrequent and often represented just a single individual from past site use. For example, *Syringa vulgaris* L. only occurred in emergent patches that were once residential sites. Based on their importance values, infrequent species contributed minimally to stand structure and function of emergent patches.

Riparian habitat: Baltimore

When compared to Syracuse forest patches, riparian patches in Baltimore showed a different pattern of occurrence for non-native species. First, only four non-native tree species – *A. platanoides*, *A. altissima*, *M. alba* L., and *Paulownia tomentosa* (Thunb.) Steud. – occurred in riparian habitats (Table 12.2). Of these, none were ubiquitous, and only *M. alba* was common, occurring on only 11 of 33 plots (Table 12.3). The other three species were infrequent.

Discussion

The data indicate that non-native tree species occurrence and prevalence were related to patch history and site disturbance. In the emergent forest patch type, non-native tree species were the most prevalent, and occupied a dominant component of the structure when compared to remnant and riparian forest patch types (Zipperer, 2002). Sites that developed into emergent forest patches resulted from the cessation of management activities or urban land use. The lack of management or use resulted in sites being available for native and non-native regeneration and establishment. In contrast, remnant forest patches were already established and any available sites for germination and colonization resulted either from the death of existing trees or shrubs, or from a disturbance (Brand & Parker, 1995). So, fewer sites for germination and establishment may exist in remnant patches.

Another difference between emergent and remnant forest patches was patch size. Emergent forest patches were generally <1 ha whereas remnant forest patches were >1 ha and the majority were >5 ha. Consequently, emergent forest patches were primarily edge communities with environmental conditions favourable for shade-intolerant species such as *A. altissima*, *M. alba* and *P. avium*.

A number of papers discussed invasibility of forest patches, with the focus principally on disturbance patterns. Emergent and remnant forests had similar types of disturbances, but emergent forest patches were disturbed more frequently and had a greater severity and extent of disturbances (Zipperer, 2002). Each of these factors increases the probability of invasion by non-native species (Lodge, 1993).

However, remnant forest patches are not resistant to non-native species. *R. cathartica*, a shade-intolerant species, was ubiquitous and a dominant component of the small diameter class (≥2.5–9.9 cm DBH). It occurred primarily along edges. Likewise, *A. platanoides*, a shade-tolerant species, occurred along edges but also in the interior of remnant forest patches. Because of its shade tolerance, *A. platanoides* may pose a greater threat to these forest patches than *R. cathartica*. In a recent paper, Martin *et al.* (2008) discuss the importance of shade tolerance when evaluating the invasibility of forest patches. In a forest, shade tolerance of woody species plays an important role in the regeneration and growth of a species. Shade-intolerant species occur principally along edges although they may occur in the interior when occupying large gaps (>500 m) (Bormann & Likens, 1979). *R. cathartica* occupies this role. By comparison, shade-tolerant species can occur along edges and in the interior. They can also exist for long periods of time in the understorey, and release only when there is sufficient light for growth. *A. platanoides* occupies this role and occurs in different strata (seedling, sapling, and overstorey) throughout a forest patch. Over time, *A. platanoides* may increase its effect on stand dynamics as it continues to establish itself and grow within the patch.

The distribution of non-native trees in the riparian habitat was different than that observed for upland habitats. In the riparian habitat, no non-natives species were ubiquitous and only one species, *M. alba*, was common. Two factors may affect non-native species distribution. First, the observed non-native species were upland species and not species commonly associated with riparian habitats. Their occurrences within this habitat may be related to fluctuating water tables within this riparian system. Groffman *et al.* (2003)

observed that the water table in the urban portion of the watershed was considerably deeper (1 m or more) than the water table in rural portions of the watershed. The drier conditions may have enabled upland species to establish themselves. Second, although the habitat is periodically dry, periodic flooding from storm run-off may, however, create saturated conditions that may inhibit extensive colonization of non-native, upland species. Further, the scouring effect from an increased stream flow following a storm may also prohibit non-native species from establishing themselves.

Conclusion

Site history and disturbance regime appear to play an important role in the distribution of non-native tree species in urban forest patches. Emergent patches are significantly affected by non-native tree species more so than either remnant forest patches or riparian habitats. Although native species – *Acer negundo* L. and *Acer saccharum* Marsh. – do occur on these sites, the dominance of non-native tree species may continue because of the suite of factors (site availability, species availability, and species performance) influencing vegetation dynamics. This is not to say that remnant forest patches are "protected" from non-native species. The combination of shade-intolerant and -tolerant non-native tree species is a major threat to the long-term viability of these sites. Shade-intolerant non-native tree species can affect forest regeneration along the perimeter of the patch, whereas shade-tolerant tree species can affect regeneration throughout the patch.

The presence of only four, non-native tree species in riparian habitats and the occurrence of these species as only common or infrequent were not expected findings. Since most non-native tree species are upland species, water-table depth and periodic flooding are thought to play an important role in limiting the distribution of non-native tree species in riparian habitats. Additional research, however, is needed to determine the factors that influence germination and establishment of both non-native and native species in riparian habitat.

References

Bormann, F.H. & Likens, G.E. (1979) *Pattern and Process in a Forested Ecosystem.* Springer-Verlag, New York.

Brand, T. & Parker, V.T. (1995) Scale and general laws of vegetation dynamics. *Oikos*, 73, 375–380.

Carreiro, M.M. & Tripler, C.E. (2005) Forest remnants along urban-rural gradients: examining their potential for global climate research. *Ecosystems*, 8, 568–582.

Curtis, J.T. & McIntosh, R.P. (1951) An upland forest continuum in the prairie-forest border region of Wisconsin. *Ecology*, 72, 476–496.

Gregg, J.W., Jones, C.G. & Dawson, T.E. (2003) Urbanization effects on tree growth in the vicinity of New York City. *Nature*, 424, 183–187.

Groffman, P.M., Bains, J.B., Band, L.E. *et al.* (2003) Down by the riverside: urban riparian ecology. *Frontiers in Ecology and the Environment*, 1, 315–321.

Lodge, D.M. (1993) Species invasions and deletions: community effects and responses to climate and habitat change. In *Biotic Interactions and Global Change*, eds. P.M. Kareiva, J.G. Kingsolver & R.B. Huey, pp. 367–387. Sinauer Associates, Sunderland.

Mack, R.N., Simberloff, D., Lonsdale, W.M., Evans, H., Clout, M. & Bazzaz, F.A. (2000) Biotic invasions: causes, epidemiology, global consequences, and control. *Ecological Applications*, 10, 689–710.

Martin, P.H., Canham, C.D. & Marks, P.L. (2008) Why forests appear resistant to exotic plant invasions: intentional introductions, stand dynamics, and the role of shade tolerance. *Frontiers in Ecology and the Environment*, 7, No: 3, pp. 142–149 DOI: 10.1890/070096.

McDonnell, M.J. (1988) The challenge of preserving urban natural areas. *Journal of the American Association of Botanical Gardens and Arboreta*, 3, 27–31.

Nowak, D.J. & Dwyer, J.F. (2000) Understanding the benefits and costs of urban forest ecosystems. In *Handbook of Urban and Community Forestry in the Northeast*, eds. J.E. Kuser, pp. 11–25. Kluwer Academic/Plenum Publishers, New York.

Reichard, S.H. & White, P.S. (2001) Horticulture as a pathway of invasive plant introductions in the United States. *Bioscience*, 51, 103–113.

de Root, R.S., Wilson, M.A. & Boumans, R.M. (2002) A typology for the classification, description and valuation of ecosystem functions, goods, and services. *Ecological Economics*, 41, 393–408.

Zipperer, W.C. (2002) Species composition and structure of regenerated and remnant forest patches within an urban landscape. *Urban Ecosystems*, 6, 271–290.

Zipperer, W.C., Burgess, R.L. & Nyland, R.D. (1990) Patterns of deforestation and reforestation in different landscape types in central New York. *Forest Ecology and Management*, 36, 103–117.

Conservation Science and Practice Series

Urban Biodiversity and Design

Edited by

Norbert Müller, Peter Werner & John G. Kelcey

ZSL
LIVING CONSERVATION

WILEY-BLACKWELL
A John Wiley & Sons, Inc., Publication

2010
626 pp