Urban Forestry & Urban Greening 18 (2016) 25–33

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Biotic homogenization of China's urban greening: A meta-analysis on woody species

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ARTICLE INFO

Article history:
Received 21 November 2015
Received in revised form 14 April 2016
Accepted 8 May 2016
Available online 14 May 2016

Keywords:
Biotic homogenization
Greening species
Urban green space
Urbanization

ABSTRACT

Human preferences for the species in urban greening have greatly facilitated the spread of non-native species, resulting in the homogenization of urban plant communities across spatial scales. We selected 11 major cities along the Yangtze River in China and examined the species composition in their urban plant communities. We found that China's urban plant communities are becoming homogenized, as urban communities of different cities are highly similar to each other despite the geographical separation. Meanwhile, these artificial communities we investigated have diverged greatly from the natural communities at both the city and the geographic scale. We recorded a total of 91 woody species that have been used in urban greening in all 11 cities. Of those species, 27% were cultivars and introduced species, and 25% were being used outside of their native distribution ranges in China. This may be explained by the market and urban planners who tend to favor greening plants that are highly profitable and have aesthetic ornamental traits, rather than spending time introducing and acclimatizing the native species in each city. Given the current trend of homogenization, measures that recognize the importance of native species should be emphasized with comprehensive urban planning strategies.

1. Introduction

Urbanization has profoundly affected the global biodiversity (Lambin et al., 2001; McKinney, 2006; Grimm et al., 2008; McDonald et al., 2008). As critical outcomes of urbanization, habitat alteration and human-assisted dispersal of species have led to the reduction or extirpation of regional and endemic native species, while expanding the distribution of cosmopolitan, non-native species (or introduced, alien, exotic, and non-indigenous species). This generally indicates increasing similarity of species composition between different areas, known as 'biotic homogenization' (McKinney and Lockwood, 1999).

Urban green spaces provide aesthetic and recreational services for people (Fuller et al., 2007; Mitchell and Popham, 2008; Łopucki and Kiersztyn, 2015), and the construction of urban green spaces has greatly facilitated the spread of non-native species, resulting in the homogenization of urban plant communities across spatial scales (Kühn et al., 2003; Kühn and Klotz, 2006; La Sorte et al., 2007). To date, human preferences for species in urban greening has been regarded as an important driver for the homogenization of urban plant communities (McKinney, 2006; Williams et al., 2009). Nevertheless, this driving force is subject to a number of mediating factors, including both natural and socio-economic influences such as levels of biodiversity, spatial distances between urban spaces, climatic conditions, human population size, and the age of the cities (Qian and Ricklefs, 2006; McKinney, 2008; Kendal et al., 2012; Lososová et al., 2012; La Sorte et al., 2014). So far, it remains unclear whether or not the homogenization of urban communities shares the same pattern globally, considering that the mediating factors may vary across countries and cities.

China spans a huge geographical area and is home to more than 30,000 vascular plants (McNeely et al., 1990). The Yangtze River basin region, in particular, harbors a rich biological diversity and huge amounts of hydrological energy, and is becoming an economic hotspot in China (Xie, 2003; Hara et al., 2014). Human use of the

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http://dx.doi.org/10.1016/j.ufug.2016.05.002
1618-8667/

land in this region, such as agricultural activities, has a remarkably long history (Ellis and Wang, 1997; Xu, 2004; Long et al., 2007). In recent decades, due to accelerated industrialization and urbanization following the economic reforms and population increases, the land-use has undergone rapid and dramatic changes (Li, 1999; Yang and Li, 2000; Wu et al., 2004). Hence, this region offers valuable opportunities to learn about the consequences of anthropogenic activities on terrestrial floras. Most importantly, China's diverse natural resources provide essential references for those artificial urban communities. Wilson (1929) described China as the 'Mother of Gardens', documenting the critical role played by Chinese plant species, especially in the Yangtze River basin region, in the urban greening of both domestic and western cities. Studying and comparing the species composition in urban plant communities in this region while considering the region's natural background and land-use histories, are of great value for solving current problems in urban planning.

In this study, our objectives are to investigate whether or not China's urban plant communities are becoming homogenized, compare species composition in urban plant communities, and explore the potential determining factors if homogenization is occurring. Our investigation and evaluation involved the following steps. First, we checked whether or not urban plant communities show high similarity across major cities in the Yangtze River basin region. Second, we investigated the similarities between urban and natural communities within each city, and addressed the distance decay of similarity relationships for all pairs of cities. The purpose was to see if divergence was occurring between the urban and natural communities at the city and geographic scale. Lastly, we looked into species' origins and ornamental traits to understand the preferences for greening plants in the Yangtze River basin region, and to infer how human selection of plants would determine the compositional characteristics of the current urban plant communities.

2. Materials and methods

2.1. Data collection

We compiled a database of the floristic composition, including lists of species of both urban and remnant natural plant communities, for 11 major cities along the Yangtze River (latitude 25°2.3334′–32°3.7002′N, longitude 102°43.0998′–121°27.4836′E) in China. The Yangtze River is 6380 km long and drains an enormous basin of 1.17 million km^2 (Liu, 2008). The 11 cities investigated in this study are Kunming, Guiyang, Chengdu, Chongqing, Changsha, Nanchang, Wuhan, Hefei, Nanjing, Hangzhou, and Shanghai (Fig. 1). Of these 11 cities, 6 are located in the middle subtropics, where the zonal vegetation type is evergreen broad-leaved forest, while 5 are in the northern subtropics where the zonal vegetation type is mixed evergreen and deciduous broad-leaved forest. Mean annual temperatures of the 11 cities range from 14.9 to 25.3 °C, and annual precipitation ranges from 1000 to 1700 mm. The warmth index (WI) and coldness index (CI) of Kira (1945) ranges from 118.9 to 160.7 for all cities, and from −2.4 to −0.2 for cities in the Northern subtropics, respectively (Table 1; Zheng et al., 2010). In this study, "urban plant communities" refers to the woody plant communities, which play a major role in terms of biomass in landscape, and ecological and botanical dimensions (Jim, 2002). Also, woody plant communities persist longer in urban green spaces compared to species that are intensively managed in herbaceous communities in China; thus, they are more representative of a city's urban planning strategies.

We searched the literature using the China National Knowledge Infrastructure (CNKI; http://cnki.net) and ISI Web of Science (http://webofknowledge.com) databases to obtain original studies. We used a combination of city name and keywords (i.e., urban greening, landscape planting, park greening, square greening, urban road greening, campus vegetation, and residential greening) to build a species list of urban greenings for the 11 cities. To search for Chinese articles, we used the corresponding Chinese names and keywords with CNKI. We read through the literature and recorded the species names that occurred in each study; and then compiled a binary presence-absence matrix where each row was an urban greening species; each column a city; and the entries represented the presence (1) or absence (0) of the species in the city. We also prepared species presence-absence matrices for different urban habitat types to elaborate on the similarities between urban communities of different cities. The urban habitat types we selected in this study are: urban park and square greening; road greening; campus greening; and residential area greening.

After completing the species list of urban greenings for the 11 cities, we recorded the growth form (i.e., evergreen tree, deciduous tree, evergreen shrub, and deciduous shrub), the geographical distribution of the wild populations, ornamental traits, and resistance to atmospheric pollution (i.e., sulfur dioxide, chlorine, hydrogen fluoride, mercury, ammonia, ozone, and dust) of each species from the literature, if available (Jiangsu Institute of Botany, 1978; Song et al., 2000; Flora of China Editorial Committee, 2013).

We also compiled a binary presence-absence matrix for the remnants of natural plant communities in each of the 11 cities. The remnants of natural vegetation usually include patches of original natural vegetation that have been deliberately preserved in cities or have been simply left as they were. They would be expected to reflect a city's original floristic characteristics (Florgård, 2009; Yang et al., 2014). To collect species composition data for the remnants of natural communities, we selected one mountain within each of the 11 cities (Xishan Mountain in Kunming, Qianling Mountain in Guiyang, Qingcheng Mountain in Chengdu, Jinyun Mountain in Chongqing, Tianzi Mountain in Wuhan, Dashu Mountain in Hefei, Xishan Mountain in Nanchang, Zijin Mountain in Nanjing, Tianmu Mountain in Hangzhou, and Sheshan Mountain in Shanghai) and recorded species names occurred in those studies (retrieved from CNKI and ISI Web of Science) that surveyed the natural communities on the targeted mountains. We considered the species composition data collected for each mountain to be the remnants of natural communities of each city, as a mountain in this case is considered as one sampling site in a city.

Finally, expert knowledge was sought to help check and review the species presence-absence data for both urban and remnant natural communities of the 11 cities. The geographical distributions of the wild populations of each greening species were reviewed by an experienced taxonomist to ensure their accuracy. Scientific names and taxonomic classifications of the greening species were based on the system used in the Flora of China (Flora of China Editorial Committee, 2013).

2.2. Data analysis

We relied on the Jaccard similarity index (J) to measure the similarity of species composition in the different locations (McKinney, 2004). We define J as: $J = c/(a + b + c)$, where a is the number of species unique to the first site, b is the number of species unique to the second site, and c is the number of species in common at both compared sites. J ranges between 0 and 1, where a result of 0 means that the two sites have no species in common, and a result of 1 means that the species composition of the two sites are identical.

We checked the similarity of the urban plant communities with each other for the 11 cities by calculating J in pairs of cities, and then summarized J by city. We also calculated J for the similarities between urban and natural communities within each of the 11 cities to see if the urban communities of a city were diverging from