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Research paper

Factors driving the vascular plant species richness in urban green spaces: Using a multivariable approach

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HIGHLIGHTS

- We analyzed plant species richness in green spaces with a multivariable approach.
- Species groups were affected most by different combinations of driving factors.
- Green space size was most relevant factor driving vascular plant species richness.
- Patch shape and distance to the urban edge were of minor relevance.
- Urban green spaces larger than 6 ha should be given priority in being conserved.

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ABSTRACT

Many studies have shown high vascular plant species richness in urban areas and, especially, in its green spaces. However, little is known about the factors driving the numbers and proportions of different species groups. The aim of our study was to test for the effects of patch size, patch shape, and distance to the urban edge as well as the combined effects of these factors on the numbers and proportions of total, native, non-native, endangered, ornamental, and nitrophilous vascular plant species. We conducted vascular plant surveys in 32 urban green spaces in the city of Hannover, Germany. We detected positive correlations between patch size and total, native, non-native, endangered, ornamental, and nitrophilous vascular plant species numbers and the proportion of endangered species by Spearman's rank correlations and linear regressions. A more compact patch shape, calculated by the shape index, affected the proportion of native, non-native, and ornamental species positively. Testing combined effects of factors with multiple linear regressions underlined the importance of patch size in combination with distance to the urban edge, and in combination with distance and patch shape. We conclude that in the context of recent urbanization processes, it is most important to create and conserve large urban green spaces (>6 ha) in order to maintain vascular plant species richness. As species groups were affected most by different combinations of driving factors, our study highlights the importance of using multivariable approaches for detecting effects more precisely.

1. Introduction

Urban areas are heterogeneous and complex mosaics of different ecosystems (Pickett et al., 2011) that have the potential to support a rich and diverse range of plant species (Angold et al., 2006; Kowarik, 2011). Plant species diversity patterns in urban areas have been extensively studied (e.g. Hope et al., 2003; McKinney, 2006; Pyšek, 1993). Recent research focused on the relevance of urban green spaces to support vascular plant species richness (Bigirimana, Bogaert, Cannière, Bigendako, & Parmentier, 2012; Gaston, Warren, Thompson, & Smith, 2005; Wania, Kühn, & Klotz, 2006). Common types of urban green spaces include parks, cemeteries, allotments, forests, and fallow lands. Urban green spaces provide habitats for a high vascular plant species richness (Knapp, Kühn, Mosbrugger, & Klotz, 2008; Kühn, Brandl, & Klotz, 2004) and, therefore, may fulfill basic nature conservation functions (Li, Wang, Paulussen, & Liu, 2005; Niemelä, 1999).

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Vascular plant species richness is an important issue in biodiversity conservation and allocates equal importance to all species, although individual species or species groups have different values for conservation. Therefore, species are often grouped, for example by their status (native, non-native, or endangered) (Magurran, 2004). In previous studies different species groups in urban and village areas have been investigated (Huwer & Wittig, 2013; Pyšek et al., 2004). These studies described the plant species composition and/or changes in species groups over time. In urban areas non-native species may replace native or endangered species and may even become pest species (McKinney, 2002). As urban green spaces are highly altered by humans, the numbers of ornamental and nitrophilous species are good indicators of anthropogenic influence. Additionally, increasing distance to the urban edge can be used as an indicator for increasing anthropogenic influence (Huwer & Wittig, 2013). Some studies focused on the total vascular plant species richness in urban green spaces (Cornelis & Hermy, 2004; Knapp et al., 2008). Other studies indicated that high total species numbers in large green spaces may be due to high numbers of neophytes (Gregor, Bönsel, Starke-Ottich, & Zizka, 2012; Kühn et al., 2004; Pyšek, 1993), which is probably due to an increase of edge effects in cities (Borgmann & Rodewald, 2005; Duguay, Eigenbrod, & Fahrig, 2007). An important step for biodiversity conservation is to achieve a better understanding of factors influencing total species richness and to know the species richness of different species groups, including their proportions.

Factors known to be decisive for vascular plant species richness in urban green spaces include patch size (Angold et al., 2006), patch shape (Knapp et al., 2008), distance to city center (Hope et al., 2003), heterogeneity of habitats (Blair, 1996; Čepelová & Münzbergová, 2012; Zerbe, Maurer, Schmitz, & Sukopp, 2002), and surrounding land uses (Guntenspergen & Levenson, 1997). Other studies have pointed to the relevance of the variability of the physical environment (Sukopp, 2004), disturbance and human interference (Bertoncini, Machon, Pavoine, & Muratet, 2012), and age of habitat (Drayton & Primack, 1996) for species richness. However, it is evident that many factors affect vascular plant species richness (Pausas & Austin, 2001). Thus, a multivariable approach is needed to understand the effects on vascular plant species richness (Matthies et al., 2013). Identifying the factors that have the greatest effect on vascular plant species richness will allow urban planners to manage for high diversity in urban green spaces.

In this paper we focus on three factors that affect vascular plant species richness and which can be influenced by urban planning: patch size, patch shape, and the distance of urban green spaces to the urban edge. As urban green space size increases, species number generally increases (Ricklefs & Miller, 2000; Sukopp & Wittig, 1993). This species–area relationship is well-known and has been documented for a variety of habitats (e.g. Berglund & Jonsson, 2001; MacArthur & Wilson, 1967). Similar species–area relationships have been observed for urban green spaces, such as fallow lands in England (Angold et al., 2006), and urban and suburban parks in Belgium (Cornelis & Hermy, 2004; Hermy & Cornelis, 2000). The shape of urban green spaces affects vascular plant species diversity in that as patch compactness decreases, plant species diversity increases due to increased edge effects (Ricklefs & Miller, 2000). Knapp et al. (2008) regarded the perimeter of green spaces as an important factor influencing vascular plant species richness, but excluded it from analysis as it was correlated to patch size. Additionally, the distance of urban green spaces to the urban edge has an inverse relationship to species richness; as the distance increases, species richness decreases for various taxa (McKinney, 2006). Previous studies have most commonly used the distance of urban green space toward the city center to address the subject (e.g. Hope et al., 2003). The underlying assumption was a linear decrease of green spaces toward the more urbanized city center. However, cities rarely show such a simple relation. Cities actually show a far more complicated mosaic of more or less urbanized areas without a single center. Therefore, the distance of each urban green space to the surrounding landscape is probably a more relevant factor defining species richness than the distance to the city center. Indeed, along an urban to rural land use gradient the species richness increased from rural over suburban to urban stands for the herbaceous layer and from suburban over rural to urban stands for the shrub layer (Guntenspergen & Levenson, 1997). In another study the highest species richness of vascular plants (wild growing as well as cultivated woody) per km^2 was detected in the transition zone between the city center and the outskirts (Zerbe et al., 2002). We conclude that the relation of species richness to patch size is already well-examined, its relation to patch shape has been rarely examined, and its relation to distance to the urban edge has not yet been examined.

Studying the vascular plant species richness in urban green spaces needs to address the response of different species groups in relation to multiple explanatory variables with emphasis to urban ecological planning. Additionally, variables that influence total vascular plant species numbers, as well as numbers and proportions of species groups in urban green spaces, may be interrelated. This information is crucial in order to allow urban planners to retain, to develop and to manage urban green spaces for optimal biodiversity conservation.

The aim of our study was to analyze the factors driving the vascular plant species richness in urban green spaces using a multivariable approach. This analysis was carried out on both potentially explanatory variables of vascular plant species richness and potential response variables of dependent species groups. Specifically, we addressed the question of how single and combined factors of patch size, patch shape, and distance to the urban edge, affect total species numbers as well as numbers and proportions of native, non-native, endangered, ornamental, and nitrophilous vascular plant species in urban green spaces.

2. Methods

2.1. Study area and selection of study sites

We conducted our study in the city of Hannover, Germany (52°23′N, 9°42′E). Hannover covers an administrative area of 204.14 km^2 with 53% built-up area, 14% agricultural area, 14% open space, 11% forests, 4% water bodies, and 4% other land uses. The city is located in a warm temperate climate with a mean annual temperature of 9.6 °C and a mean annual precipitation of 661 mm.

Within the Hannover study area a total of 32 urban green spaces were selected as study sites using a stratified random sampling approach (Fig. 1). A combination of three classes of patch size with three classes of distance to the urban edge was used for the sampling. First, we identified the urban edge using detailed land cover data from a digital landscape model (LGN, 2007). The urban edge was defined as the border of the coherent built-up area (measured as all land cover class objects dominated by sealed surface, for example residential building area, industrial area) with gaps not exceeding 100 m. Within the urban edge, all patches primarily covered by vegetation (land cover class objects dominated by vegetation, for example parks, forests) were identified as green spaces. Subsequently, we categorized the green spaces as small (0.5 ha to 2 ha), medium sized (>2 ha to 6 ha), or large (>6 ha to 100 ha). The distances of each green space to the urban edge was calculated (measured from the centroid of a polygon) and its location categorized as close to the urban edge (>50 m to 1000 m), medium distance from the urban edge (>1000 m to 2000 m), or far from the urban edge (>2000 m). Study sites were selected regardless of vegetation type and vegetation structure. Out of each combination of