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Research paper

Effects of settlement size, urban heat island and habitat type on urban plant biodiversity

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HIGHLIGHTS

- Detailed study on the effect of settlement size on urban plant diversity.
- Biodiversity change studied on specific habitat types with different disturbance regime.
- The effect of heat island on species temperature requirements determined by city size.

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ABSTRACT

Urbanized areas with high habitat heterogeneity and intense human impact form unique environment which is surprisingly rich in plant species. We explore the effect of the settlement size on plant species richness, composition and temperature requirements of plant communities.

We studied three habitats with different disturbance regime in 45 Central European settlements of three different sizes. We sampled 1-ha plots in each habitat by recording all spontaneously occurring vascular plant species. We divided recorded species into groups according to their origin and residence time and according to their temperature requirements based on Ellenberg indicator values. We used ordination methods and ANOVA to detect that species communities in urban areas are generally more species rich in larger settlements than in small ones. These differences are mostly pronounced in residential areas. Increasing settlement size is significantly reflected by neophytes that are dependent on constant input of propagules caused by human activities and by native species that survive in remnants of semi-natural vegetation in urban environment. In contrast archaeophytes as a homogeneous group of species with similar traits are widespread equally through settlements of all sizes. We did not confirm the effect of urban heat island on species composition, indicating that species composition is significantly more affected by local habitat conditions than by urban size. Our results highlight the importance of urban size as important factor shaping biodiversity of native and alien plant communities in individual urban habitats and the important role of habitat mosaic for maintaining high species richness in city floras.

1. Introduction

Human settlements form a specific environment that is unique in its characteristics and intrinsic conditions, which strongly affect biodiversity (McKinney, 2006). The interior of each settlement is composed of a mosaic of numerous different habitats of various sizes. The resulting heterogeneity reflects different human activities, the diverse history of the area and various local conditions (Kühn & Klotz, 2006; Lososová et al., 2012a). Habitat heterogeneity (Kowarik, 1995; Kühn, Brandl, & Klotz, 2004) together with the high input of seeds that increases with the level of urbanization and the city size (Luck & Smallbone, 2011; Pyšek, 1998) lead to high plant species diversity in total urban floras (Deutschewitz, Lausch, Kühn, & Klotz, 2003; Klotz, 1990; Kühn et al., 2004; Stadler, Trefflich, Klotz, & Brandl, 2000).

From the perspective of island biogeography (MacArthur & Wilson, 1967), cities can be considered as a type of ecological island isolated from the other city islands by the surrounding landscape (Begon, Townsend, & Harper, 2006; Clergeau, Croci, & Jokimäki,

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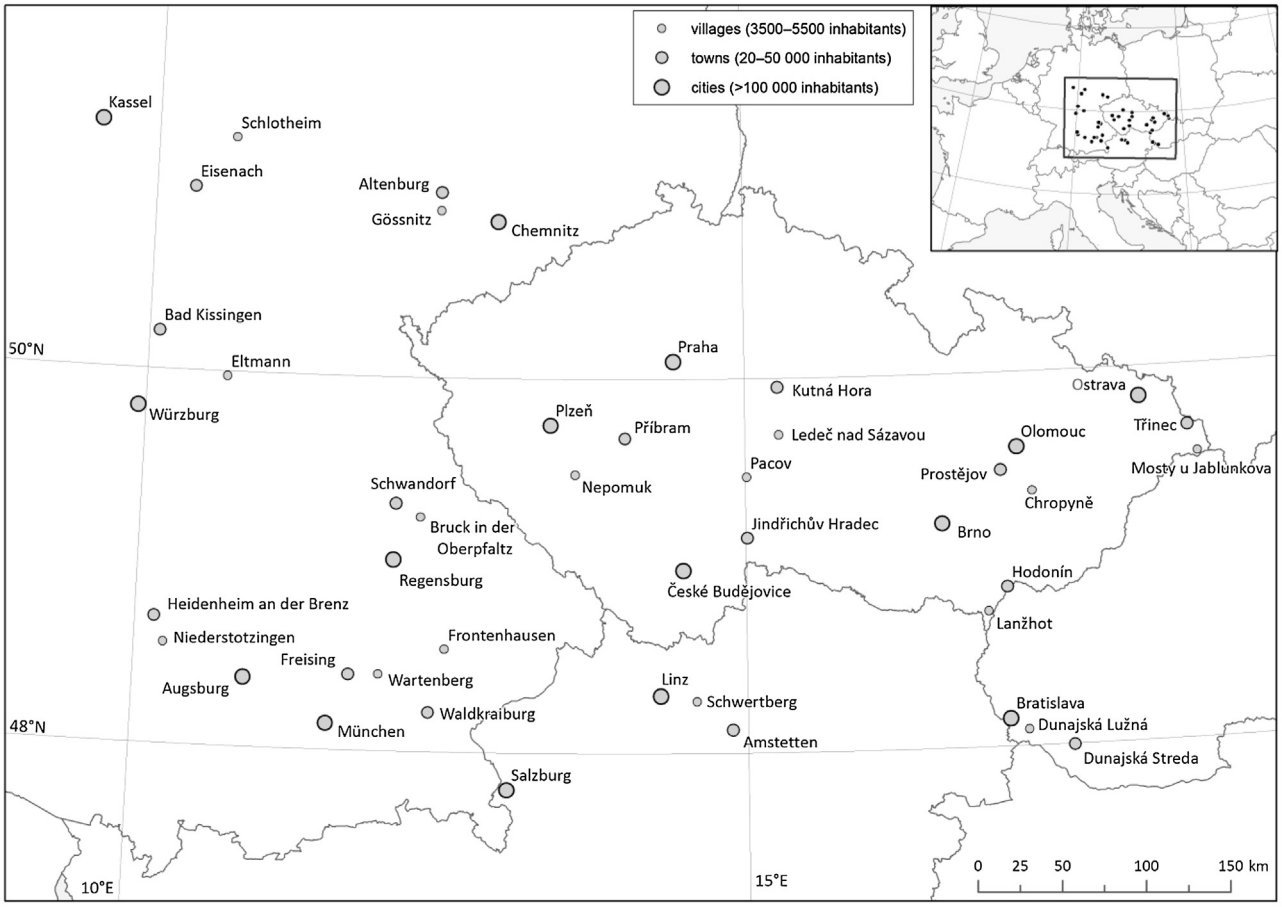

Fig. 1. Map of studied settlements.

2004; Davis and Glick, 1978; McGregor-Fors, Morales-Pérez, & Schondube, 2011). Because city islands are not completely isolated from the surrounding landscape, many generalists could be present both inside and outside the settlement, but it has been shown that the species-area relationship exists in both isolated as well as not completely isolated systems (MacArthur & Wilson, 1967; Preston, 1962; Williams, 1964). Previous studies have demonstrated that the total number of species on an island is a function of its area (Begon et al., 2006; Cain, 1938; Connor & McCoy, 1979; Rosenzweig, 1995). In human settlements as well, the total number of species increases with the city size (Pyšek, 1998), most likely due to the high number of different habitats in urban areas (Boecklen, 1986; McIntyre, 1995; Winter, Johnson, Shaffer, Donovan, & Svedarsky, 2006). It is assumed that the city size could affect not only the total species number within the city as a whole but also the species richness of individual habitats. The diversity of vegetation in isolated urban habitats depends on the balance between colonization and extinction (MacArthur and Wilson, 1967). We assume that in small cities, fewer patches of the same habitat type occur and that these patches are usually smaller than in large cities. This is why such habitats would host fewer species in smaller populations, which can be more prone to local extinction (Dupré & Ehrlén, 2002; Jackson & Sax, 2010; Tilman, 1994). Moreover, in urban habitats, colonization and extinction are also affected by human management (Marzluff et al., 2008). A similar pattern has been well-documented in urban bird communities (e.g., Garaffa, Filloy, & Bellocq, 2009; Jokimäki & Kaisanlahti-Jokimäki, 2003). There are practically no studies that have focused on the effect of city size on plant species richness in individual habitats. Large cities with a heterogeneous mosaic of habitat types, high traffic, industry and high population density could most likely host more plant species than small settlements on comparably sized plots in similar habitats due to the higher availability of dispersal vectors and types of seed sources.

The city size can also have different effects on species with distinct origin and residence time. For remnant populations of native species surviving in urban areas, a city of large size could mean greater isolation from populations growing in the surrounding rural landscape and therefore a reduced possibility of propagule input. This could lead to the local extinction of some species and therefore a reduction in their species richness. The opposite could be true for alien species. Their occurrence in urban areas is associated with human activities such as cargo traffic, planting and landscaping or trading activities (Dunn & Heneghan, 2011; Pyšek, 1998). As a consequence, a higher proportion of alien species can be found in the urban environment than in the surrounding rural landscape, as has been shown for several cities in Europe (Kühn & Klotz, 2006; Pyšek, 1993; Wania, Kühn, & Klotz, 2006). Because the proportion of alien plant species in urban floras increases with city size (Klotz, 1990; Pyšek, 1998), larger cities are considered to be an important source of alien species for their subsequent spread to smaller settlements and the surrounding landscape (Pyšek, 1998).

Large built-up urban areas with impervious surfaces made of concrete, asphalt and pavement, along with heat and smog pollution, contribute to changed climatic conditions in settlements in comparison with the surrounding landscape. The so-called urban heat island (UHI; Landsberg, 1981; Oke, 1982) is manifested by higher temperatures measured in urban areas and is highly pronounced in large settlements (Gaston, Davies, & Edmondson, 2010). It is predicted that the species composition of urban vegetation is