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Original article

Applicability of Modified Whittaker plots for habitat assessment in urban forests: Examples from Hannover, Germany

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ABSTRACT

In ecological planning, cost-effective but accurate methods for the assessment of habitats and species are needed. In this study we investigated whether the multi-scale Modified Whittaker plot (MWP) method is suited for vascular plant surveys as a basis for habitat assessment. We measured total and endangered species richness in ten urban forests in Hannover, Germany. The MWPsí time efficiency and effectiveness in capturing species richness were quantified and compared to complete field surveys. The MWP method estimated both greater and lower species numbers per habitat, the absolute deviation ranged from +60 to −15 species. It generally captured fewer endangered plant species than the complete field survey. In particular, the method did not detect species with a high category of endangerment. Regarding time efficiency, the MWP method took an average of 186 minutes per habitat, while the complete field surveys were more time consuming (mean = 265 minutes). In small habitats (<1.0 ha) the full survey took less time than the MWP method. To determine the applicability for nature conservation and ecological planning, we evaluated the species data derived from the two methods by using common habitat evaluation criteria. In most cases, the species data received from the MWP method resulted in lower habitat values compared to the use of data from the full surveys. We conclude that comprehensive habitat evaluation exceeds the applicability of the MWP method which may miss locally rare species. However, the MWP method provides an opportunity to efficiently estimate plant species richness patterns in urban forests and, thus, holds the potential to convey basic information for an overall monitoring of species diversity and may lead to specific habitat assessment efforts.

1. Introduction

Urban forests are essential features of our cityscape that have long captured the attention of scientists and practitioners, such as ecologists, social scientists and urban planners (Johnston, 1997; Carreiro et al., 2008). Due to different institutional and geographical perspectives, numerous definitions of urban forests have been presented in the literature to date (Randrup et al., 2005). The majority of these definitions have a broad perspective and refer to all planted and naturally occurring trees, as well as associated vegetation in an urban area, including parks, private gardens, streets and forest stands (Konijnendijk et al., 2006; Miller et al., 2015). However, from an ecological perspective, this broad definition of urban forests is limited (Ordóñez and Duinker, 2012).

Forest ecosystems encompass characteristic structural and functional components that differ from other tree-dominated habitats in urban areas (e.g. species composition, carbon storage). Accordingly, in the context of habitat classification, the term urban forest is used in a more narrow sense and linked to different types of woodland habitat (Smith et al., 2011). For example, forest habitats may be categorized into deciduous and evergreen woodland. Within each of these categories, a further subdivision can be made on the basis of, for example, vegetation or soil type (Douglas et al., 2011). Thus, spatial units of urban forests can be grouped according to similarities in habitat criteria, which exhibit characteristic biotic and abiotic living conditions for a population system of organisms of animal and plant species (e.g., ash-alder mixed riparian forest, poplar wood). In this paper we refer to this habitat-based perspective on forests in urban areas.

Urban forests support a diversity of urban wildlife (Alvey, 2006; Croci et al., 2008). For example, it was documented that urban forests show high species richness of vascular plants (Godefroid and Koedam, 2003; Stewart et al., 2009), birds (Sanesi et al., 2009) and mammals (Garden et al., 2007). Other studies have shown that urban forests may also harbor endangered species and species of high conservation value (Gustafsson, 2002). Urban forests may

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also constitute substantial areas for overall biodiversity, some of which meet the criteria for protected habitats, e.g. based on the European Habitat Directive (92/43/ECC) or standards for protected habitat types in national nature conservation legislations (Müller, 2011). Hence forest habitats within urban areas can make important contributions to protected area objectives if they are managed appropriately.

Ecological planning is recognized as an essential tool for obtaining information about habitats and species, on the basis of which strategic decisions for enhancing biodiversity can be derived (Sukopp and Wittig, 1993; Gödde et al., 1995). In ecological planning, conservation assessments often apply relatively simple, but robust and cost-effective methods. They are often based on legal standards and principles of nature conservation and management. Habitat assessment is such a method, because it allows for an evaluation on the basis of a comprehensive habitat mapping (Southerland, 1993; Starfinger and Sukopp, 1994). Habitat mapping is nowadays a common task in urban ecological planning (Sukopp and Weiler, 1988; Löfvenhaft et al., 2002).

As habitats and plant species are related, there is often overlap between their assessment and evaluation (Bunce et al., 2013). Plant species are essential attributes that define habitat types. At the same time, habitats vary in species richness. Species richness is the most commonly used measure of biodiversity (Gaston, 1996). Species richness is often used in monitoring programs to provide quantitative information on the dynamics of overall biodiversity, e.g. within a habitat or a habitat-mosaic (Weber et al., 2004). Nevertheless, to use species richness as a criterion for habitat evaluation is difficult because high species richness does not necessarily mean a high conservation value. The natural community of a habitat may be relatively homogenous or species-poor. For example, peat bogs represent habitats of high ecological value that are characteristically species-poor. On the other hand, degraded habitats can show high species numbers, although species of high conservation value may be missing (Tucker, 2005). Therefore, species richness, in itself, is not a comprehensive value but should be evaluated in the context of its ability to shape a specific habitat and in the context of the relevant spatial scale. Habitats may also encompass plant species of conservation concern (Muratet et al., 2008). Evaluations made on the basis of habitats are, therefore, often underpinned through selective recording of plant species, especially with respect to the presence of endangered species (Rüter and Opdam, 2016). Examples from many cities, mainly located in Germany, demonstrate that habitat evaluations based on plant species data have been routinely used in urban planning since the early 1980s (e.g., Trepl, 1983; AG Stadtbiotopkartierung, 1985).

Various methods are available for the survey of vascular plants which have proved useful for the purpose of ecological planning (Rich et al., 2005a; Sutherland, 2006). However, each of these methods are characterized by specific advantages and disadvantages. One such method is a complete field survey (cf., true census, systematic total count), which aims for a comprehensive detection of all plant species in a given area (Krebs, 1989; Chiarucci and Palmer, 2005). Another important group of methods encompasses sample based techniques, e.g. transects, quadrat-based and nested plots (Palmer, 1990; Rich et al., 2005b; Stohlgren, 2006). In particular, their application by surveyors, their effectiveness (detectability of species) and their efficiency (time, financial costs) can differ between each method and, thus, might hamper their applicability in practice.

Stohlgren et al. (1998) noted that innovative, multi-scale methods should replace the commonly used transect methods to better evaluate the status and trends of both common and rare plant species. One important multi-scale method is the Modified Whittaker plot (MWP) method. The method was developed by Stohlgren et al. (1995) and based on the work of R.H. Whittaker (described by Shmida, 1984). The MWP method was introduced as a tool that allows for standardized estimation of local species richness. Species richness is calculated on the basis of regression lines that are generated for single habitats by a species assessment in a nested plot design. Thereby the method takes into account the species-area relationship, as would be predicted from the classical island biogeography (MacArthur and Wilson, 1967).

To date, several studies have been conducted describing the application of the MWP method (Stohlgren et al., 1998; Campbell et al., 2002). For example, Barnett and Stohlgren (2003) compared MWPs with other methods in a nested-intensity sampling design in aspen stands in southern Colorado. They found that the MWP method allowed for a comparison of species richness in the sample sites, whereas small, single-scale plot techniques underestimated species richness by missing locally rare species.

One could argue that the use of multi-scale methods might improve the efficiency of habitat assessment because species information is provided at lower costs (time) than by complete field surveys. Nevertheless, complete field surveys are more precise. They provide complete species list and, therefore, enable for an evaluation of the true species richness as well as for an evaluation of specific species groups (e.g., endangered species). For urban ecological planning, this raises the question of whether complete field surveys are required and worth the (time) effort when multi-scale methods are effective and with less expenditure.

In this study we explore the applicability of the MWP method for the assessment of urban forest habitats. Specifically, we analyze the MWPsí time efficiency and effectiveness in quantifying total and endangered vascular plant species richness as compared to complete field surveys. We determine how the use of species data, derived from MWPs, influences the results of habitat evaluation and, thus, discuss how the MWP method can facilitate urban ecological planning.

2. Methods

2.1. Study area and study sites

The research was conducted in the city of Hannover, which is located in the north of Germany in humid Central Europe (52°22′32.72 N, 9°43′54.49 E). We defined the urban area as a continuous built-up area showing high amounts of sealed surfaces. Within the urban area, we selected all forest habitats using an area-wide habitat map of the region of Hannover (Region Hannover, 2013a). Urban forests cover an area of 908.6 ha, which is 6.2% of the urban area. We randomly chose ten forest habitats as study sites. The study sites include beech forest, birch forest, oak-hornbeam forest, poplar plantation, reforestation of deciduous forest, and woody succession area. The size of the study sites varied between 0.6 ha and 7.7 ha.

2.2. Sampling design and inventory

Field work was performed from May to July 2013. We conducted both the MWP method and complete field surveys at each study site. The MWP design and placement followed the description of Stohlgren et al. (1998) and NIISS (2013). The nested design contains one major plot (1000 m^2), one 100 m^2, two 10 m^2, and ten 1 m^2 subplots (Fig. 1a). The MWPs were placed along the major environmental gradient in a representative section of each habitat. Separate species lists were compiled for each of the plots. Average species numbers for the 1 m^2 and 10 m^2 plots, as well as the recorded species numbers for the 100 m^2 and the 1000 m^2 plots, were used to generate regression lines and estimate species richness for the whole area of forest habitat. Power functions were