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Diversity of street tree populations in larger Danish municipalities

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ABSTRACT

Healthy and sustainable tree populations require a high diversity of genera and species. This study examined the occurrence and contents of tree inventories in Denmark's 30 largest municipalities. 59% of the municipalities had a tree inventory for street trees, but only about half of these were complete and updated. Only one municipality had a registration for trees other than street trees. Based on data from the tree inventories, the diversity of road side trees was analyzed at genus level and species level. A total of 82,072 street trees are part of the study. 11 different genera account for 92% of the total street tree stock, and 2–6 genera account for 40–80% of the street tree stock in the individual municipalities. *Tilia* was the most dominating genera (26%). 12 species account for 73% of the total street tree stock. The 6 most common species account for almost 50% of the total tree population. The species representing the largest numbers were *Tilia* × *europaea* (12%), *Acer platanoides* (10.9%), *Platanus* × *acerifolia* (7.2%), *Tilia cordata* (7.2%), *Fraxinus excelsior* (6.2%) and *Sorbus intermedia* (5.9%). The four most urbanized municipalities had a surplus of non-native species, but all municipalities apart from one had most street trees belonging to native species. The concluding recommendation of this study is that tree managers need to start working more strategic with their tree stock, in order to reduce the vulnerability, due to potential attacks from pests or diseases and climate change effects. A risk spreading system for the urban tree population is proposed, suggesting that no genera should account for more than 10% and no species for more than 5% of the tree population.

1. Introduction

Street trees contribute esthetically and architecturally to urban areas and roads, and are beneficial to the environment and the quality of urban life in a number of ways. Trees help reduce the "urban heat island effect" (Sieghardt et al., 2005), and decrease the need for energy for cooling and heating of buildings (McPherson and Rowntree, 1993; Simpson and McPherson, 1996; Maco and McPherson, 2003). Urban trees help reduce noise, hide industrial activities, reduce air pollution, thereby improving air quality and views for the gain of citizens (Beckett et al., 2000; Nowak et al., 2006, 2008). Trees contribute to urban hydrology by reducing storm water runoff (Tyrväinen et al., 2005; Sieghardt et al., 2005; McPherson et al., 2011). Green areas and trees have a stress reducing effect and people who are using green areas close to their home feel more healthy and are more physically active (Grahn and Stigdotter, 2003; Bedimo-Rung et al., 2005; Maas et al., 2006; Schipperijn et al., 2010). However, the prerequisite for these benefits is a healthy urban tree population, free from calamitous pests and diseases.

During the recent years, serious problems with pests and diseases in combination with increasing urbanization and potential climate changes put pressure on urban trees worldwide. The proposed key to assure a healthy and sustainable urban tree resource in the future is a higher diversity of genera and species, together with more focus on species adapted to the harsh urban conditions (Richards, 1982/1983; Sæbø et al., 2005; Raupp et al., 2006; Bassuk et al., 2009; Sjöman et al., 2012). Prime example of a disease with extensive impact on the street tree population must be the "Dutch Elm Disease" (DED), caused by the fungus *Ophiostoma ulmi* (Buism.) Nannf. or *Ophistoma novo-ulmi* Brasier, which killed millions of Elm trees all over Europe, North America and Asia (Butin, 1995). But also the more recent "Ash Dieback", caused by the fungus *Chalara fraxinea* T. Kowalski (Bakys et al., 2009), or the "Canker stain of Plane" caused by *Ceratocystis fimbriata* (Ell.

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& Halsted) Davidson f. sp. *platani* Walter (Panconesi, 1999) affect widely used street tree species and emphasize the importance of using a broad range of species. Several definitions of a sustainable urban tree distribution have been proposed over the last decades. Barker (1975) divides the species into four categories, where no species may exceed 5% of the total population. Grey and Deneke (1986) recommend that no single species should account for more than 10–15% of the total population. Smiley et al. (1986) state that no species should exceed 10% of the population. Moll (1989) is the first to propose limits on genus level, recommending that no species should account for more than 5% and no genus should account for more than 10% of a tree population. Santamour (1990) extends the recommendations further to also include family level, and recommends that no species should account for more than 10%, no genus for more than 20% and no family for more than 30% of the total tree population. Miller and Miller (1991) suggest that no species should account for more than 10% of the total population. Bassuk et al. (2009) recommend that the total share of any species should be limited to between 5 and 10% of the urban tree population. Strategic recommendations like the above are valuable guidelines regarding how to obtain increased species diversity. However, international surveys on species diversity indicate that recommendations are not followed (Richards, 1982/1983; Smiley et al., 1986; Pauleit et al., 2002; Frank et al., 2006; Raupp et al., 2006; Ningal et al., 2010; Kurunei-Chitepo and Shackleton, 2011; Sjöman et al., 2012; Yang et al., 2012; Cowett and Bassuk, 2014). Although the number of species or genera may appear high, typically a few genera or species dominate.

The evident tool for the analysis of the diversity of a tree population is a tree inventory. On a strategic level, knowledge about the current species distribution is essential in order to be able to identify potential problems and be able to make substantiated decisions (Miller, 1997; Wandall and Randrup, 1999; Pauleit, 2003; Ningal et al., 2010; Gerhardt and Weller, 2011; Keller and Konijnendijk, 2012). On a more tactical level, a tree inventory has been proposed as efficient tool for systematic management of urban trees, (Miller, 1997; Saretok, 2006; Gerhardt and Weller, 2011; Nielsen et al., 2014). Also, tree inventories allow sharing of information between municipalities, especially if registered parameters have been standardized (Sjöman and Nielsen, 2010; Keller and Konijnendijk, 2012).

Whereas the use of tree inventories among the larger Danish municipalities is increasing, there has so far been no attempt to systematically analyze their contents. Selected Danish municipalities have participated in international surveys on former occasions, e.g. in a European survey carried out by Pauleit et al. (2002) with participation of 17 countries. Questionnaires were sent to the 5 largest towns and cities, of each country, but from Denmark only Copenhagen participated. Later, Sjöman et al. (2012) made a survey exclusively for the Nordic region. Tree inventory data was requested from ten Nordic cities with more than 200,000 inhabitants. The countries and cities participating were Denmark (Aarhus and Copenhagen), Finland (Espoo, Helsinki, Tampere and Turku), Sweden (Gothenburg, Malmo and Stockholm) and Norway (Oslo).

Both of the above studies concluded that typically 3–5 genera account for more than 50% of the tree population. In a study by Sæbø et al. (2005), based on data from the European survey by Pauleit et al. (2002), data was analyzed further to find possible differences between species diversity in street environments compared to all urban environments, including streets, parks and urban woodlands. Both surveys showed a higher number of different species in parks than in street environments (Sæbø et al., 2005; Sjöman et al., 2012). The larger number of species found in park environments are explained with the often more favorable growth conditions in parks and urban woodlands compared to those of street trees (Sæbø et al., 2003). But even with park trees included in the analysis, typically a few species dominate the urban tree population (Pauleit et al., 2002; Sæbø et al., 2005; Raupp et al., 2006; Sjöman et al., 2012). This lack of diversity indicates the necessity and importance of a full review of the Danish tree population in order to evaluate national risks for the urban tree population and to be able to recommend how to avoid future risks.

A relevant issue when discussing an increase of diversity is the use of native versus non-native species. The predicted climate changes may improve growth conditions for some species and worsen conditions for other species (Roloff et al., 2009; Thomsen, 2012). For Denmark, annual precipitation is expected to increase with 9%, but with an uneven distribution resulting in more precipitation during winter and less in the growth season. The annual mean temperature will increase with 2–3 °C, and storm frequency will increase (DMI, 2007). The future situation may very well be that growth conditions for some native species will become unfavorable, whereas some non-native species are better adapted to future climatic conditions in Denmark (Sjöman, 2012). However, the introduction of non-native species is not entirely without risk and the possible impact of new species on existing ecosystems should be examined as well (Parker et al., 1999; Hitchmough, 2011). To be able to give a full evaluation of the vulnerability of the urban tree populations, it is therefore interesting to know the number of native versus non-native species in the municipalities.

Based on this introduction, the present study has the main objective to collect, examine and discuss the current distribution of street trees in Danish municipalities based on data from municipal tree inventories, and, based on this survey, to discuss recommendations for municipalities aiming at a balanced street tree population with low susceptibility to calamities.

2. Materials and methods

For this purpose, an inquiry was sent to the 30 largest Danish municipalities (out of a total of 98 municipalities), defined by the number of inhabitants living in urban areas (Ministry of Economy & Internal Affairs, 2011). The largest municipality was Copenhagen with 539,542 inhabitants; the smallest was Svendborg with 58,713 inhabitants. Out of the 30 municipalities, one municipality did not wish to participate in the study. The green space departments of the municipalities were requested to provide information about the existence and use of a tree inventory, a copy of their complete tree database and information about their management of urban trees.

The municipalities participating are evenly distributed all over the country. The amount and type of data available in tree inventories differed between the municipalities. Therefore, municipalities with electronic tree inventories were asked to convert data into excel-format before handover. Data from three municipalities was provided as a photocopy and data had to be put into excel manually afterwards. A total of 16 out of the 29 municipalities (55%) had a tree inventory with available data (Fig. 1). Of these 16, only Aarhus had data for trees other than street trees, i.e. for park trees and urban woodlands. However, the data for park trees also includes trees from the botanical garden in Aarhus. Having no other Danish park tree data to compare with, and given the fact that the data include trees in a botanical garden, where obviously the purpose is to display diversity, the park tree data from Aarhus was excluded from further analysis. As a result, only diversity of street trees has been analyzed for this study. Of the 16 municipalities with an inventory, 8 had a complete inventory of street trees, implying that all street trees (100%) in the municipality have been registered, but regardless to which taxonomic level. The remaining 8 municipalities had completed their registration to a varying degree. (Table 1).