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Understanding how built urban form influences biodiversity

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ABSTRACT

This study seeks to contribute to a more complete understanding of how urban form influences biodiversity by investigating the effects of green area distribution and that of built form. We investigated breeding bird diversity in three types of housing development with approximately the same amount of tree cover. No significant differences in terms of bird communities were found between housing types in any of the survey periods. However, detached housing, especially with interspersed trees, had more neotropical insectivores and higher overall diversity of insectivores. Based on our results and theory we suggest a complementary approach to managing biodiversity in urban landscapes – instead of maximising the value and quality of individual patches efforts could go into enhancing over-all landscape quality at the neighbourhood scale by splitting up part of the green infrastructure. The relatively small differences in bird communities also suggest that different stakeholder groups may be engaged in management.

Introduction

Within the coming two decades, the world will see the addition of nearly 1 million km^2 of urban areas (McDonald, 2008). Urban development has already generated some of the greatest local extinction rates of species (McKinney, 2002), and is predicted to have the single largest effect on terrestrial ecosystems in the 21st century (Sala et al., 2000). This means that the form and pattern of new urban areas will affect the world's ecosystems in profound ways. However, knowledge on what role urban form plays in terms of biodiversity is still in its infancy, constituting a black box in urban design and planning.

Cities represent self-organising systems of unusual complexity (Portugali, 2000; Batty, 2005; Miller and Page, 2007), comprising different kinds of self-organising systems, such as social networks, economic markets and ecological systems that all interact with each other. Cities without urban planning and design do not lack order, but rather present both highly developed structures and predictable processes, albeit not necessarily the structures and processes that make them well posed to deal with the pressing problems of climate change and loss of biodiversity and ecosystem services (Marcus and Colding, 2011). The professional practice of urban design is geared at trying to influence different self-organising systems in the city, for example pedestrian movement or the distribution of retail, by the structuring and shaping of urban space (e.g. Hillier and Hanson, 1984). Characteristic for urban design is that this is accomplished using very concrete media such as the structuring and shaping of buildings and landscapes, that is, the *built form*. Hence, urban space as structured and shaped by built form, is used in urban design to intervene in different urban systems, and therefore also the medium that urban designers need to master to shape and navigate urban development in more sustainable directions (Marcus and Colding, 2011).

This study seeks to contribute to a more complete understanding of how urban built form influences biodiversity. It is placed in the context of suburban landscapes, which are known to provide diverse mosaics and resources for biodiversity (e.g. Marzluff and Rodewald, 2008). However, the paucity of empirical studies directly comparing spatial organisation of urban development and combinations of land uses/land cover – at this level of urbanisation – has so far generated limited clues for urban design. Nevertheless, a number of ecological studies have addressed how different types of land use influence biodiversity (Fernandez-Juricic, 2000; Smith et al., 2006; Andersson et al., 2007; Colding and Folke, 2009). Moreover, Colding (2007) outlines how different land uses can be configured and combined for greater support of biodiversity and ecosystem services by way of 'ecological land-use complementation'. Shifting focus from individual areas to whole landscapes potentially opens up new opportunities for design. Within landscape ecology terms like interspersion and juxtaposition have long been used to describe the spatial configuration of different patches in a landscape (e.g. Forman, 1995). Smaller size and higher shape complexity increase the length of borders among different kinds of patches and thus resource accessibility and potential for complementation. Together, complementation and interspersion could

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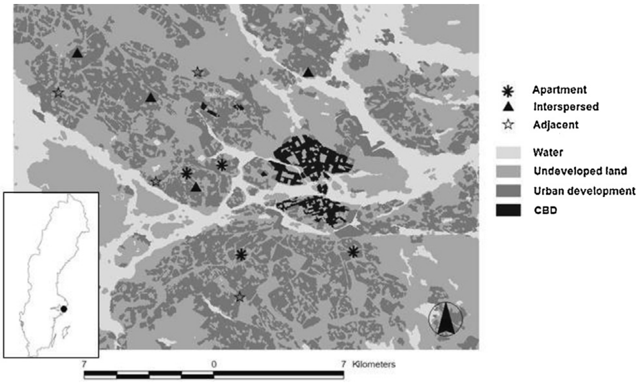

Fig. 1. Location of field sites in Stockholm. The three site types are apartment buildings, detached houses with interspersed clumps of trees and detached houses adjacent to a larger forest. The smaller map in the lower left corner shows Stockholm's location within Sweden.

be an interesting tool for finding and promoting synergies when planning and designing new urban development.

In this paper we address how urban form influences biodiversity by conducting replicated surveys in Stockholm, Sweden, of avian biodiversity in three types of housing development with approximately the same amount of formally recognised green areas, in this case mixed forest. We analyse and discuss biodiversity differences in terms of species diversity, species composition and functional redundancy. We place our results in the context of urban land use planning at a neighbourhood (sensu Hersperger, 2006) scale and public engagement in green area management.

Methods

Study area

Stockholm is situated at the boundary between the northern hemisphere boreal zone and the mid-European nemoral zone, and at the outlet of the freshwater lake Mälaren into the brackish Baltic Sea (59°20′ N, 18°05′ E) (Fig. 1). The physical landscape is shaped by the last glacial period 10,000 years ago, followed by human settlement and cultural practices and it consists of fissured bedrock, clay-covered valleys, and a small-scale rough terrain with a range of habitats conveying a relatively high biodiversity. The Stockholm Metropolitan Area hosts a current population of 1.4 million people; it is the most rapidly growing and most densely populated region in Sweden with 2700 inhabitants/km^2 (SCB, 2010). Densification has been identified as the most desirable development trajectory (Regionplanekontoret, 2010; Stadsbyggnadskontoret, 2010).

Site attributes

Three different types of housing areas were investigated: detached houses with interspersed clumps of trees/small groves, detached houses next to a larger woodland (>10 ha), and apartment buildings with extensive treed commons (Fig. 2). All three types are relatively "greener" than many more recent housing developments. Four sites from each category were chosen for the study and subsequently surveyed for breeding birds. All sites had approximately the same amount of non-garden green areas, primarily woodland or treed commons within a sample area of 300 m × 300 m. Sample areas had to be limited to 300 m × 300 m to avoid too much variation within the sampling. Housing areas in Stockholm are limited in size and on a larger scale land use is quite heterogeneous. Average coverage of impervious surfaces was 35%, with no significant differences between the different types of housing. Most of the development took place between 1900 and 1950, and all sites were at least 40 years old. All sites can arguably be called suburban, based both on location (Fig. 1) and general character (Fig. 2).

Bird surveys

We used the point count method of surveying bird species and their abundances at each site (Bibby et al., 2000). Four survey points were located within each site, distanced 100 m apart and at least 100 m from the sample area boundaries. In the areas with housing next to woodlots two of the survey points were located in the woodlot and two in the housing area. Surveys were conducted three times: in early April, late April/early May and late May/early June 2011. We chose survey periods to cover the annual peak in singing activity, from the early breeding resident birds to migrant passerines. Daily surveys were begun at first light, at approximately 5:30 am in early April and from 3:30 am late May/early June, and finished at latest 2.5 h later. This period overlapped with the daily peak in bird vocal activity. Surveys were only conducted in mornings with favourable weather conditions, i.e. low winds and no heavy rain.

Each point was surveyed for 5 min and the number and identity of all birds seen or heard within 50 m were recorded, with the exception of overflying individuals. This threshold distance was chosen to capture only those birds located within the site, to avoid double counting birds at two survey points, and because it is substantially less than the maximum distance observers are estimated to be able to differentiate the distance to calling birds (i.e. 65 m, see Alldredge et al., 2007). An additional 5 min was spent walking between the points, where all species seen or heard within 50 m from the path was noted (only presence) to get an as complete as possible species list for the different sites. Due to the density of vegetation, most identification was made acoustically, rather than visually. In cases of uncertainty, the most conservative estimate of abundance was used.

Statistical analyses

Data were first explored by comparing species numbers and numbers of individuals across sites using one-way ANOVAs. Second, differences and/or similarities in community structure between the three types of housing development were described using non-metrical multidimensional scaling ordination (MDS), a method used to represent relative dissimilarities as distance in low-dimensional space (Clarke, 1993). Stress, or goodness of fit, was calculated as described by Kruskal (1964), within Primer and using 25 iterations. Similarity matrices were based on Bray Curtis distances. Statistical relationships between bird communities were then tested with PERMANOVA analyses, packaged in R as "adonis" in the library (vegan). The program gives a partitioning of multivariate variation according to individual factors in any fully balanced multi-way ANOVA design, with tests done by permutations (Anderson, 2005). Further description can be found in McArdle and Anderson (2001) and Anderson (2001), where the method is referred to as "permutational manova". Data was analysed in two ways: either untransformed, using the relative abundances of different species, or divided into functional groups based on diet and then computed based on the number of species within the different functional groups. Each survey period was analysed separately, meaning we ran 2 different analyses on each survey result. *P*-Levels were adjusted accordingly. As the dietary groups differed substantially both in terms of the number of species and the number of individuals we tested species number distributions individually for the three groups using one-way ANOVAs, with adjusted *P*-levels. Resulting differences were then further investigated in terms of presence and abundance of individual species within the groups. All statistical analyses were done in R (version