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Research Paper

The effect of urban park landscapes on soil Collembola diversity: A Mediterranean case study

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ABSTRACT

By increasing landscape patchiness and habitat loss, urbanization threatens biodiversity. Its adverse effects may be mitigated by urban parks, in which conditions that promote structural and functional biodiversity contribute to preserve ecosystem processes. Therefore, deep knowledge of urban park biodiversity and of patterns driving species assemblages is required, especially for soil communities which are understudied. This study, conducted in public parks in Montpellier (Southern France), is the first one examining the impact of landscape patterns on Collembola communities. Moreover, soil abiotic properties were analyzed to examine how local factors drive species assemblages in different landscape types. The results of the study highlighted that Collembola community structure is affected by landscape patterns. Specifically, Collembola communities with species-abundance structures typical of late successional stages were found within woody landscapes, whereas those with early successional stage structures were observed in wide turf patches surrounded by other vegetation covers. When turf patches become small and isolated, homogenization was observed in Collembola community composition. From the perspective of urban park planning, managers should consider limiting landscape fragmentation (*i.e.* interspersion and configuration of impervious surfaces) and preserving landscape diversity (especially through woody vegetation patches). These may promote the development of diverse and structured Collembola communities, indicators of the overall soil quality.

1. Introduction

During urbanization, cities expand their boundaries and ecological footprint (Grimm et al., 2008), increasing landscape patchiness (Wu, 2014) which, together with habitat loss, is a major cause of biodiversity decline (McKinney, 2002). Representing the main green surfaces within cityscapes, urban parks supply benefits to city dwellers (de Vries, Verheij, Groenewegen, Spreeuwenberg, 2003; Nowak et al., 2008) and constitute important biodiversity hotspots in cities (Nielsen, van den Bosch, Maruthaveraan, van den Bosch, 2014). However, urban park communities usually suffer from biotic homogenization, being mainly characterized by the replacement of local communities with others constituted by few ubiquitous and opportunist species (McKinney, 2002). Understanding the drivers shaping urban biodiversity is a novel challenge with pivotal implications for conservation plans (Wu, 2014; Nielsen et al., 2014). In particular, the fundamental role of habitat and microhabitat diversity of large and old urban parks in guaranteeing high species richness has been widely recognized (Braaker, Ghazoul, Obrist, & Moretti, 2014; Nielsen et al., 2014). The relationship between urban landscape mosaic and community biodiversity has been mainly studied in above-ground communities of organisms such as plants, arthropods, gastropods and birds (e.g. Braaker, Ghazoul et al., 2014; Braaker, Moretti et al., 2014; Chong et al., 2014; Concepción et al., 2016; Pickens et al., 2017; Threlfall, Williams, Hahs, & Livesley, 2016). For instance, the isolation of parks from other urban green areas facilitates exotics and generalist species (*i.e.* urban exploiters and

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adaptors) implying community simplification and shifts, as well as limitation of animal movements (Braaker, Moretti et al., 2014; Chong et al., 2014; Concepción et al., 2016; Nielsen et al., 2014). Conversely, the effects of park patch size differently vary according to the territory required to maintain viable population sizes (Nielsen et al., 2014). Nevertheless, how landscape characteristics affect belowground communities has scarcely been explored.

As an important component of soil fauna, Collembola (Apterygota: Hexapoda) can represent, together with Acari, 95% of soil microarthropods (Seastedt, 1984), organisms with body length from 0.08 to 8.8 mm (Ulrich & Fiera, 2010). Colonizing all terrestrial ecosystems, Collembola play fundamental roles in several ecosystem processes such as soil carbon sequestration and nutrient cycling (*e.g.* Endlweber, Ruess, & Scheu, 2009; Seastedt, 1984; Wardle, 1999). They exhibit various feeding strategies, dispersal abilities and habitat specialization levels (Hopkin, 1997). Therefore, communities vary according to vegetation and soil physico-chemical characteristics (*e.g.* Gillet and Ponge, 2003; Heiniger et al., 2015; Loranger, Bandyopadhyaya, Razaka, & Ponge, 2001). The dependence of Collembola communities on soil characteristics makes them valued indicators of the overall soil quality (Van Straalen, 1998), routinely used in biomonitoring programs (Bispo et al., 2010). Nevertheless, Collembola remain scarcely studied in urban ecosystems (*e.g.* Devigne, Mouchon, & Vanhee, 2016; Milano et al., 2017) and, to our knowledge, very little information is available on how the urban landscape mosaic affects their biodiversity (Milano et al., 2017). Indeed, the information available on this topic mostly results from studies in agroforestry areas (da Silva, Berg, Serrano, Dubs, & Sousa, 2012; da Silva et al., 2015; Querner et al., 2013; Sousa et al., 2004, 2006), suggesting that landscape diversity may affect collembola biodiversity at different spatial scales (Sousa et al., 2004, 2006; Querner et al., 2013). At landscape scale, the increase in woody surface, albeit indirectly, benefits Collembola diversity through multiplying the ecological niches available at smaller scales (da Silva et al., 2012). Nonetheless, a multi-scale approach considering factors at both landscape and local scales has to be usually adopted in evaluating Collembola community responses to the environment (da Silva et al., 2015).

The aim of our study was to evaluate the effects of landscape patterns (*i.e.* at park scale) and local soil properties on Collembola community biodiversity in urban parks. Hence, we hypothesized that the complex patchwork of contrasting land uses, which is typical in urban parks, may shape local Collembola communities (H1), and that more diverse park landscape patterns may host the most structured species communities (H2).

2. Materials and methods

2.1. Study area

The city of Montpellier (43°36′ N, 03°52′ E; 27 m a.s.L.), in Southern France (Fig. 1a), extends over 56.88 km^2 and is characterized by a Mediterranean climate, with hot dry summers and moderate wet winters. Montpellier counted 275,318 inhabitants in 2014, with a population density of 4,840 inhabitants km^{-2} (https://www.insee.fr/fr/statistiques/1405599?geo=COM-34172) and is the eighth French city for population growth (https://www.insee.fr/fr/statistiques/1906659?sommaire=1906743). Although urbanization was accompanied by drastic land use changes, Montpellier engaged in an eco-friendly development policy since the city is member of the Convention on Biological Diversity (https://www.cbd.int/).

The present study was carried out in fourteen public parks within Montpellier (Fig. 1b) and information on their respective previous land use was obtained from municipality park office, defining four classes (Table 1): agricultural land, wood, urban or leisure estate (*i.e.* country house, folly, hunting domain).

2.2. Park thematic maps

Fourteen thematic maps of the selected public parks (Fig. 1b, c) were produced, for the landscape pattern analysis, allowing to investigate the composition (amount of land cover types) and spatial configuration (shape and relative spatial disposition of land cover types) of the patch mosaic (McGarigal, Cushman, Neel, & Ene, 2002). In particular, the 14 vector maps have been produced by photo-interpretation of 2014 aerial photographs of Montpellier (data from National Geographical Institute), using a Geographical Information System (GIS) software (QGIS Development Team, 2014). Five land cover classes, specific to this project, have been defined to code the different cover types observed from aerial photographs and validated in the field: “open vegetation” (turf), “closed vegetation” (evergreen and deciduous woods), “impervious surfaces” (paved parkways, cobblestone paths, buildings, fountains, playgrounds), “other vegetation” (hedgerows, shrubs, tree-lined rows, orchards, vegetated dog park zones), “single tree” (few sparse trees) (Fig. 1c). Land cover information was provided for each polygon and stored in the attribute table. The perimeter and area of each polygon were calculated by GIS and used to compute the selected landscape metrics.

2.3. Spatial scale and metric selection

Centered on each sampled point, a buffer area of 35 m radius was employed for the landscape pattern analysis. Since the open and closed patch sizes can considerably vary within and among parks, the radius length has been extrapolated from the mean areas of all the open and closed vegetation patches (2493.6 and 3662.4 m^2, respectively), and used as references for a circle. Thereafter, buffers and thematic maps were overlapped and intersected. In the case of buffers larger than park boundaries, the thematic maps were expanded to neighboring lands, defining new landscape items (*i.e.* “water courses”, “sparsely vegetated areas” and “vineyards”). An example of the cartographic work is illustrated in Fig. 1c and d.

Each landscape was characterized by 2 landscape composition and 2 landscape fragmentation metrics. Landscape composition was described at class level by percentage of patches with closed vegetation (PLAND*closed*), open vegetation (PLAND*open*) and impervious surfaces (PLAND*impervious*), as well as by the landscape diversity, expressed through the Shannon’s Diversity Index (SHDI) at landscape level (McGarigal et al., 2002). SHDI was calculated considering the abundance of all patch classes with the exception of impervious surfaces and water courses, as they do not host suitable habitats for Collembola. Landscape fragmentation was characterized at class level by the density of patches with closed vegetation (PD*closed*), open vegetation (PD*open*) and impervious surfaces (PD*impervious*), as well as by the edge density (ED) at landscape level (McGarigal et al., 2002). ED was calculated considering the boundary length of all the patch classes. Detailed information on the metrics employed are reported in Supplementary Table 1.

2.4. Sampling design

Soil sampling was carried out on November 20th, 21st and 22nd 2014, in patches with open and closed vegetation only. During the week before sampling, mean air temperature was 13.7 °C (http://www.meteofrance.com/climat/meteo-date-passee). In each park, 8 or 4 sampling areas (4 m^2 each) were identified, depending on the presence of both open and closed vegetation patches or only one land cover type (Table 1). Each sampling area was located in a patch of 60 m^2 minimum. From each sampling area, a core of surface soil (0–5 cm depth, 5 cm diameter) was collected after the removal of litter (when present), according to ISO 23611-2 (2006). To allow data comparison, soil cores in closed areas were always collected under *Quercus ilex* L., the dominant native evergreen species in these parks. Here, the litter