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A comparison of 3 types of green roof as habitats for arthropods

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ABSTRACT

In an inexorably urbanizing world, green roofs could be an interesting tool to conciliate the greening of cities with ecological services. Studies on a large number of sites are necessary to understand the importance of environmental variables, especially how the type of vegetation affects the green roof biodiversity.

We sampled several arthropods (spiders, true bugs, beetles and hymenopterans) from buildings covered by green roofs in 115 sites across northern France. We considered 3 types of green roofs with diverse vegetal structures: muscinal (moss/sedum – M) roofs, herbaceous (moss/sedum and meadow – H) roofs and arbustive (moss/sedum, meadow and shrub – A) roofs.

The species richness and the abundance of most of the taxa were significantly higher on A roofs, which displayed more complex vegetation. Predominantly common species comprised the arthropod communities. However, xero-thermophilic species and species from sandy and rocky habitats were also present because green roofs could serve as habitat analogs of those dry natural habitats. Except for hymenopterans, we did not observe a difference in the functional composition of communities; however, the taxonomic composition of spider communities was significantly affected by the green roof type. The surrounding environment and other local variables exhibited a minor influence on the composition, abundance and richness of the arthropods. We revealed a major role for the vegetal structures in arthropod communities and the ability of green roofs to enhance urban biodiversity.

1. Introduction

With more than half of the human population residing in cities, which is project to rise to 70% in 2030 (UNFPA, 2011), urban areas detrimentally invade natural landscapes (Fischer and Lindenmayer, 2007), thereby impacting the entire planet (Grimm et al., 2008). Policy makers, urban planners, architects and, more recently, naturalists must (i) fulfill the basic needs of urban dwellers, such as housing, health and education (UN-HABITAT, 2008), and (ii) limit the major negative effects of urbanization by enhancing quantity and quality of natural spaces in cities. These two challenges may be difficult to reconcile but in fact they are highly interdependent. The presence of biodiversity and the services it provides could contribute to the basic human needs, such as health or well-being (Costanza et al., 1998; Dearborn and Kark, 2010; Bai et al., 2012), and greening cities and especially of buildings could help accomplish biodiversity (Jim, 2004; UN-HABITAT, 2008).

Green roofs (roofs with a substrate and a vegetated surface) may be one of the most promising ecological engineering techniques to increase green surfaces (Mitsch, 2012). Restoring habitats by removing existing infrastructure is complex due to the strong land-use conflicts in cities (e.g., housing and business pressures), thus creating habitats on existing or new buildings may be a tenable compromise (Tzoulas et al., 2007).

Historically, green roofs have been implemented for the technical benefits they provide to buildings, such as roof membrane longevity improvement, storm-water management and summer cooling (Oberndorfer et al., 2007). Furthermore, buildings with roof-gardens possess esthetic and recreational values that enhance their economic value (Liu, 2002). These benefits explain the increased presence of green roofs worldwide. For example in France, from 100,000 m^2 to 1,000,000 m^2 of green roofing has been implemented yearly for the past ten years according to ADIVET (French association of green roofing companies).

The ecological values of green roofs, such as providing shelter for numerous organisms, have only recently piqued the interest of urban ecologists, as they could shelter many organisms. Some birds have already been observed nesting in green roofs, such as the northern lapwing (*Vanellus vanellus*) in Switzerland (Baumann, 2006) and the black redstart (*Phoenicurus ochruros*) in England (Grant, 2006). However, green roofs may be even more important

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for other organisms, such as arthropods, that need small habitats to maintain viable populations (Gaston et al., 1998). Even if urban dwellers harbor a generally a negative perception of arthropods (Kim, 1993), arthropods remain “the little things that run the world” (Wilson, 1987). They represent a major component of the ecosystems and are responsible for numerous functions and services such as decomposition, pollination and biological control. Furthermore, they are highly threatened by urbanization (Hunter, 2002; McKinney, 2008).

Previous studies have stressed the importance of the presence of arthropod communities on green roofs. A community richness and composition equivalent to those of other urban green spaces were observed (Colla, 2009; MacIvor and Lundholm, 2011a; Ksiazek et al., 2012). Even rare arthropod species were observed (Jones, 2002; Brenneisen, 2006; Kadas, 2006), which piqued the potential interest in green roofs, particularly ones with structured vegetation, for conservation and ecosystem services in urban areas (Hunter and Hunter, 2008) where “people live and work” (Miller and Hobbs, 2002). The potential is strengthened by the important surface available for the settling of green roofs, which has been estimated at over 32% of the horizontal 2D surface in some cities according to Frazer (2005). These pioneer studies assessed environmental factors that could affect the distribution of species on green roofs but, unfortunately suffered from a low number of sampled sites (approximately ten per study).

Extensive and simple intensive greening (The Roof Greening Working Group, 2002) is technically divided into three main solutions that place the vegetal structures as the principal factors that change with different vegetal palettes planted at different substrate depths (Madre et al., 2012). Three vegetation layers are currently planted on buildings. They range from a unique low strata comprised of bryophytes (mosses) and succulent plants from the *Sedum* genus, typically termed as extensive roofs (M type), to more complex roofs with higher vegetal structures such as herbs (H type) and even shrubs (A type), typically termed as simple intensive roofs. These types are considered as three different levels of structural vegetation complexity.

In this study, we sampled arthropods from numerous sites (115 roofs in northern France) in order to assess whether the previous trends are representative and to identify factors that shape the arthropod biodiversity on green roofs, including the surrounding environment and other local variables, particularly the difference between green roof types (hereafter named the GR type effect).

By studying four taxa of arthropods, we answered the following questions:

(1) Does the GR type effect supported the “structural complexity hypothesis” that assumes that structurally diverse habitats (with different vegetation layers) yield more niches, thereby increasing the diversity and abundance of animal communities (MacArthur and MacArthur, 1961; Tews et al., 2004), especially arthropods (Southwood et al., 1979; Langellotto and Denno, 2004; Mormul et al., 2011)?
(2) Is there a GR type effect on the taxonomic arthropod composition?
(3) Is there a GR type effect on the ecological attributes of arthropod communities, such as the dispersal capabilities and habitat affinities?
(4) Are the arthropod communities affected by other environmental variables, such as the green roof area, building height, plant species richness, plant coverage and potential surrounding habitats?

Finally, we discussed our results and their impacts on the fields of urban planning and ecological engineering.

2. Materials and methods

2.1. Sampling design and study area

Following a green roof typology based on a significant proportion of the maximal vegetal strata (Madre et al., 2012, Supplementary Fig. 1), we considered three types of green roofs:

(1) The muscinal roof (M) is primarily composed of low-development pioneer plants such as bryophytes (mosses) or vascular creeping plants from the *Sedum* genus such as *Sedum album*, *Sedum spurium* or *Sedum sexangulare*. This type refers to extensive greening and excludes roofs that are covered by herbaceous plants on more than 20% of their surfaces.
(2) The herbaceous (H) roof is composed of the understory plants of the M roof and is covered by herbaceous plants (gramineous and other non-woody plants such as *Festuca glauca*, *Petrorhagia saxifraga* or *Allium schoenoprasum*) on more than 20% of its surface.
(3) The arbustive (A) roof is the most diverse type, composed of the previous strata and is covered of woody plants (shrubs such as *Lavandula angustifolia*, *Cotoneaster franchetii* or *Pinus mugo*) on more than 20% of its surface.

These three types correspond to different technical solutions proposed by green roofing companies, such as “Toundra”, “Pampa” and “Garrigue” (scrubland) systems by Sopranature® for example.

One hundred and fifteen green roofs were sampled, selected from green roofing companies’ databases according to their technical characteristics. A representative number of each roof type was sampled: 45 M roofs, 38 H roofs and 32 A roofs. As M roofs represent the majority of the green roofs currently implemented (estimated at 95% of green roofs in France), we studied a large area to obtain a representative sample for each type. The study was performed in northern France in the spring of 2011. The sites are located along a west–east transect of 900 km (from −4.483 to 7.787 latitude in decimal degrees) and a north–south gradient of 300 km (from 49.758 to 46.752 longitude in decimal degrees) (Fig. 1A). In this area, the landscape is primarily dominated by agricultural land uses but the green roofs are predominantly located in and around the cities (Fig. 1B).

2.2. Arthropod sampling and ecological attributes

In this paper, we adopted a multi-taxa approach and targeted four arthropod taxa: spiders (Araneae), beetles (Coleoptera), true bugs (Heteroptera) and hymenopterans (Hymenoptera: ants, wasps and bees). These taxa encompass a broad range of functional aspects and especially different trophic levels: predators for spiders and predominantly phytophageous for true bugs (Heteroptera), beetles (Coleoptera) and hymenopterans. Our two constraints were (i) to sample a high number of sites and (ii) to sample all of the different taxa on the roof, including the ground level and the different vegetation layers. Thus, we adopted a standardized hand-sampling that has been shown to be less time-consuming and less labor-intensive than other methods such as pitfall traps (Gotelli et al., 2011). We standardized the hand-sampling method for both time and area to allow for a quantitative comparison between sites (Churchfield et al., 1991; Gotelli et al., 2011). For each site, we captured the arthropods in pill bottles for 10 min in a fixed band width of 2 m along a 20-m transect. Arthropods were captured from plants from all vegetal layers simultaneously. The sampling was conducted from 11 April to 7 June 2011.

The individuals were identified at a species level. Juveniles and larvae, which could not been identified at this level, were excluded from the analyses ($n = 21$).