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Building biodiversity: Vegetated façades as habitats for spider and beetle assemblages

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ABSTRACT

In a context of urban greening, vegetated façades offer a great potential to enhance urban biodiversity. Yet, little is known about the ecological drivers of such man-made ecosystems on assemblages.

We assessed four types of façades: three types of vegetated-façades – CP (climbing plant façades), FL (felt layer façades) and SM (substrate module façades) – and concrete bare wall) as a control. On 33 façades located in and around Paris (France), we compared the effects of façade type with the area, the properties of the surrounding landscape on spider and beetle assemblages.

The façade type showed major differences in their ecological, their floristic and their management specifications. CP were xerothermophilous habitats similar to cliffs, whereas SM and FL were damp and cool habitats, similar to vegetated waterfalls. These differences in local scale properties influenced more arthropod assemblages than landscape properties, which showed higher species richness and abundance in SM and lower ones in bare walls. Façade types clearly sheltered different beetles' assemblages in terms of species and traits, including more affine to damp habitat in SM and FL than the other types. Despite the presence of few rare species of Northern France, the assemblages of spiders were dominated by generalist species.

Our results show the capacity of vegetated façades to shelter arthropods and argue for their development in cities.

1. Introduction

Since humans started building, plants have colonized their façades, creating shelters for wildlife. Approximately 2000 years ago, vine (*Vitis vinifera*) was widely planted on walls in the Mediterranean region, providing shade and fruit for people and also forming the earliest vertical gardens (Köhler, 2008). More recently, the transformation or adaptation of walls to support vegetation, referred to as vertical greenery of buildings, has emerged and is of particular interest to engineers, architects, planners and now ecologists as it could provide various services to buildings and cities.

Vertical greenery has a great potential in building-dominated landscapes due to the large wall surface available, also referred to as wallscape (Francis, 2011). In England, Darlington (1981) showed that walls represent 10% of the total urban land

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surface whereas Grimmond et al. (1991) estimated this ratio to 50% in an American city. These available surfaces depend on the morphology of the buildings and the cities and the socio-economical context (Francis, 2011). The use of vertical planting is also promising as the development of high-rise buildings with high wall-to-roof ratios is becoming widespread (Chu and Cheng, 2010). The surface area of cities is expected to double since 2030 (World_Bank, 2009) and so is the surface of walls.

"Green walls" is the most general term used to define vertical greening techniques, by analogy with "green roofs". However, this term groups different types of techniques. Vertical greening is categorized grossly into "green façades" which refer to the spreading of climbers on wall surfaces, and "living walls" which refer to the use of felt layers or modular hydroponic systems to form a living cover (Chu and Cheng, 2010; Francis and Lorimer, 2011). Hydroponic systems primarily use fertigation (irrigation with dissolvable fertilizer) and control systems (Brohm et al., 2010). Patrick Blanc, creator of the felt layer system, uses the term "vertical garden" with a reference to the artistic composition of gardens (Blanc et al., 2008). In this paper, we will use the term "vegetated façades" as a generic term to avoid confusion with one of the technical supports studied herein (e.g., sphagnum substrate in metallic modules from the GreenWall® company, Montpellier, France) or with "green buildings", which also refer to the use of solar panels, reflective façades and others modifications.

Overall, vertical greenery provides a great number of benefits to buildings and thereby are the motivations for their installation (Wang et al., 2014). Vertical greenery systems have important effects on the temperature and energy consumption of buildings (Wong et al., 2009). Vegetated façades reduce interior temperatures and delay the transfer of solar heat, which consequently reduce power consumption in air-conditioned buildings (Cheng et al., 2010). Vegetated façades enhance air quality, by capturing pollutants such as nitrogen oxides (NOx) and volatile organic compounds (VOC) (Rondeau et al., 2012). Vegetated façades provide noise reduction (Ismail, 2013). Vegetated façades also protects walls from degradation due to harsh environmental conditions such as direct sun or acid rain (Köhler, 2008). Finally, they enhance the aesthetic value of a building to many observers, which is still the main motivation for their settlement (Köhler, 2008). Although the benefits of vertical greenings for buildings are well-known, their benefits for biodiversity remain poorly studied (Francis, 2011).

Vertical greening can be considered as a mimicry of natural vertical habitats such as cliffs covered with climbing plants or vegetated waterfalls, creating potential analogue habitats for organisms (Lundholm and Richardson, 2010). Only few studies have investigated the ecology of such "man-made cliffs", and wall ecology is still considered as a frontier of urban ecology (Francis, 2011). These studies highlighted a positive effect of vertical greening on plants, which could be explained by harsher conditions on bare walls (low accumulation of nutrients and dryer conditions) (reviewed by Francis, 2011). For fauna, the studies are really scant. Benedict and McMahon (2002) showed that the abundance of birds was greater on walls with climbing plants than on bare walls and Matt (2012) showed that walls with climbing plants could shelter much more abundant and diverse assemblages of arthropods than bare walls. Köhler (1988) reported that thermophilic, synanthropic and arborial arthropods have colonized climbing plants façades. It appears that vegetated-façades could provide habitat for fauna and, by enhancing their ecological design, they could contribute to urban biodiversity. Unfortunately, information on the effects of the characteristics of various vegetated façade types on biodiversity is still not available.

To fill this gap, we sampled arthropods on different types of façades: vegetated façades representing different technical solutions and also concrete bare walls.

We selected two major taxa of arthropods: beetles (Insecta, Coleoptera) and spiders (Araneae). Spiders and beetles are among the most diverse and abundant taxa on earth and, despite an overall negative perception (Kim, 1993), remain "the little things that run the world" (Wilson, 1987). As a consequence they are responsible for numerous functions and ecosystem services, including decomposition (Lavelle et al., 2006), pollination or biological control. Moreover, they need smaller size habitats than bigger organisms to maintain viable populations (Gaston et al., 1998). Finally, rich assemblages of arthropods can develop on other vertical natural habitats such as natural cliffs (Telfer, 2006; Růžička and Zacharda, 2010) and on vegetated infrastructures such as green roofs (Kadas, 2006; Braaker et al., 2013; Madre et al., 2013).

We investigated the effects of various environmental filters located at different spatial scale on communities properties (Keddy, 1992). We formulated the following hypothesis:

(1) The proposed typology of façades reflects differences in technical solutions but also in their habitat template (abiotic properties, Southwood, 1977) and vegetation properties.
(2) The different types of façades sheltered different assemblages considering species and traits as proposed by the "template hypothesis" (Southwood, 1977).
(3) There is an increase of species richness and abundance from poor to more complex habitats as proposed by the "structural diversity hypothesis" (Siemann et al., 1998) and a link between plant productivity and arthropod abundance (Larondelle et al., 2014).
(4) We expect a positive effect of the area of the walls on species richness, as proposed by the species–area relationship.
(5) There is a different response between the traits of organisms considered (mean size, habitat affinity).
(6) Globally, the local scale have a stronger effect on organisms than the landscape scale as most urban species have already high dispersal capabilities (Wiens, 1989).

Finally, we discussed and transferred our results through guidelines to help the ecological implementation of vegetated façades, especially regarding their environmental impacts and biotic benefits.