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## Preliminary data on low aerial plankton in a large city center, Paris



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### ABSTRACT

Some organisms are able to disperse by air through passive or active flying and can colonize highly isolated habitat. We can hypothesis than aerial dispersions could be a process of biodiversity development even in isolated town habitats such as some building roofs.

The urban aerial plankton has been poorly studied and we analyzed here the arthropods and seeds trapping small species limited to 0.5–5 mm sizes and to a low part of the atmosphere (traps on roofs below 50 meters) in Paris, a center of a very large agglomeration. Using plates of wire meshes with fat, we observed that insects are dominant (Diptera and Hemiptera) when spiders and seeds appeared underrepresented.

At high heights of buildings (and not at low heights), the Landscape Greening Index seems to have a strong positive effect on abundances for spiders, insects and seeds stressing the role of sources and the effect of building barriers on aerial dispersion. These preliminary data encourage research on this process.

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### 1. Introduction

In towns, the development and settlement of new nature areas (kitchen gardens, green roofs and walls, etc.) or of more natural management of parks with spontaneous species is well supported (Miller and Hobbs, 2002; Dallimer et al., 2011). These policies, that are now also promoted in dense urban areas, are motivated by the ecosystemic services which appear clearly important both to the well-being of citizens (pollution regulation, water management, social and sanitary benefits, etc.) and for economical topics (water and climate regulation, etc.) (Millennium Ecosystem Assessment, 2005). However, the durability of these new systems is linked to the presence of numerous species that can interact between them and, consequently, assure a “good” ecological functioning of the system (Crocì et al., 2008; Heim and Lundholm, 2014). So the presence of numerous spontaneous plants and animals is desirable. Species translocation of animals in urban areas seems limited both economically and ecologically speaking. The process of species dispersion in cities between green spaces then seems important. The main objective of green frameworks, such as those developed in France, is to permit these dispersions. As in rural and suburban areas, corri-

dors can match in dense urban areas (Ahern, 1995; Clergeau, 1997) but are less frequent.

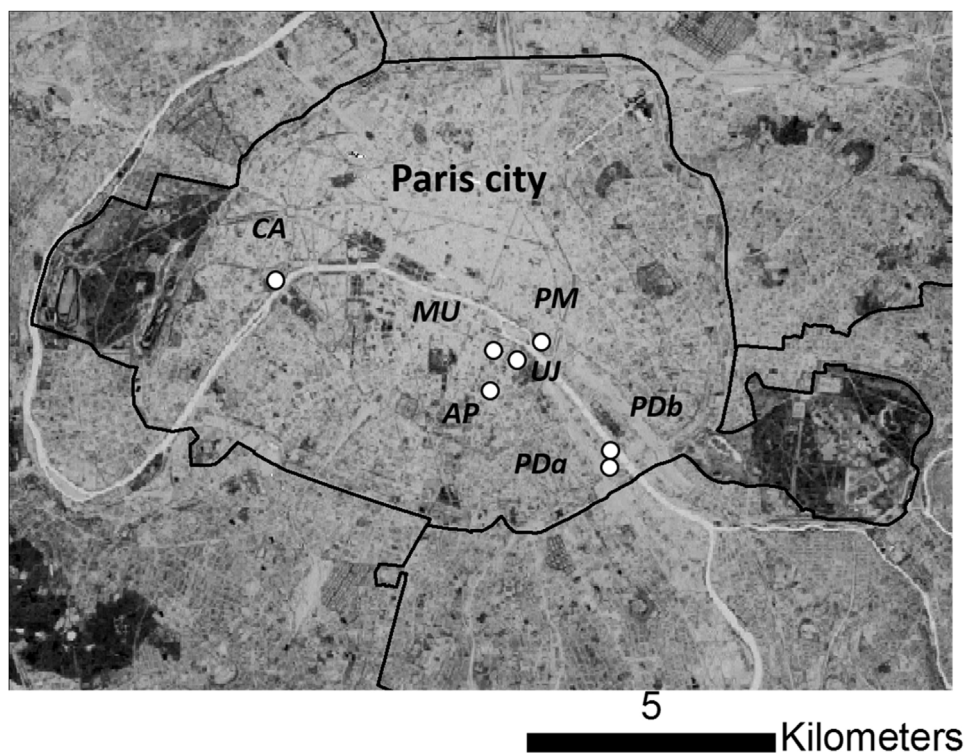
Some organisms are able to disperse by air through passive or active flying like birds or invertebrates. Spiders are known to disperse by creating a silk balloon and move on the air over long distances (Bell et al., 2005). With this way of dispersal spiders are able to colonize highly isolated habitats. Progress in radar techniques also allowed researchers to detect frequent mass aerial migrations of arthropods such as carabids (Chapman et al., 2011). So, many small organisms are frequently present in the air and form the aerial plankton by analogy with the marine plankton (Chapman et al., 2004).

In urban landscapes, “natural” habitats are frequently distant from each other and separated by structures such as buildings that clearly limit the movement of many species, even those capable of aerial dispersal (Lizée et al., 2011; Peralta et al., 2011). Many authors have considered that those habitats are so isolated that they operate like habitat islands (Faeth and Kane, 1978; Balkenhol et al., 1991; Fernández-Juricic and Jokimaki, 2001; Clergeau et al., 2004). However those studies did not consider vegetated roofs. In an urban context, vegetated roofs are increasing and recent studies have shown their importance as habitats or as potential connectivity elements for arthropods (Madre et al., 2013) or spontaneous flora (Madre, 2014).

Generally, aerial dispersal in towns has been poorly studied (but see Balkenhol et al., 1991), but this knowledge has the potential to

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**Fig. 1.** Localization of the seven sampled sites and Normalized Difference Vegetation Index (NDVI) map. NDVI represents photosynthetic values and varied along an increasing grey scale color. Low values are represented by light grey and are mainly buildings and roads. High values are represented by dark grey and are vegetated areas such as urban parks.

help us understand both which and how small organisms can colonize new green areas such as vegetated roofs, and which species can invade or damage these areas. We present here a first study on the aerial plankton limited to 0.5–5 mm sizes and to a low part of the atmosphere (below 50 m) where we can expect a maximum number of individuals due to strong movement of air (vehicles, street canyons, etc.). We wanted to know what arthropods could be present and if aerial plankton included seeds that could factor in the dynamics of green roofs. We also test whether height of the roof and greening context could influence catch rates. We chose the city of Paris that can be defined more as a city center than as a city, with levels of soil sealing reaching 80% (Vergnes et al., 2014), and without real suburbs that surround greater Paris (especially allotments with small gardens). Here, we can test the responses of aerial plankton in a very large “city center”.

## 2. Methods

### 2.1. Sampling design

Seven sites distributed in Paris have been sampled (Fig. 1; Tableau 1). We have used 20 × 40 cm plates of wire meshes with fat (see Appendix A for methodology design). In each site, a sample involving 2 or 3 plates was settled vertically on roofs or guard rails, in different directions, and always in a most clear possible environment, e.g. without wall at immediate proximity. We avoided putting our traps at street level (less than 10m) as short dispersions of seeds have already been studied here (von der Lippe et al., 2013).

Two trapping periods of 15–20 days each were conducted in autumn (October 2014) and spring (April 2015). We sampled 78 plates overall. To homogenize the trapping times and the numbers of plates, abundances are given per plate and per 100 days and then transformed into integers to be used as count data.

In each site, we measured the height and the landscape Greening Index (Table 1). The Landscape Greening Index is based on the NDVI (Normalized Difference Vegetation Index) taking account a 500 m radius around each site. NDVI was calculated on Landsat 8 images (30 m resolution, NASA Landsat Program 2014), it is based on the photosynthetic activity for a given pixel (Kerr and Ostrovsky 2003). The Landscape Greening Index reflects the potential source for aerial plankton around sites and is frequently using in urban landscape studies (Vergnes et al., 2012; Madre 2014). It has been calculated using ArcGis 10.1.

Plates of wire were collected from the roofs and analyzed at laboratory. Organisms were extracted and identified: seeds (to the family level) and Arthropods (classified in arachnids or insects at the order level).

### 2.2. Statistical analysis

We have analyzed the abundances of insects, arachnids and seeds. Data from autumn and spring did not show significant differences (Wilcoxon test,  $p=0.91$ , 0.70 and 0.60 respectively) and were pooled.

We tested the effects of the interaction between height and NDVI using Generalized Linear Models (GLM) with a Poisson error distribution, particularly adapted for zero-rich data such as count data (Crawley, 2009). Then, we ran an Anova type 2 to assess the significance of parameters. To better interpret the interaction, the results were plotted using the package effects.

## 3. Results and discussion

In all, we collected and identified 10 211 arthropods (6447 in spring and 3764 in autumn) and 46 seeds (respectively 29 and 17) in our different sites and periods.

**Table 1**  
Characteristics of sampled sites (height of plates and the landscape Greening Index) and mean numbers of Arachnids, Insects and Seeds caught per 100 days and per plate.

| Site | Height of roof (m) | Landscape Greening Index | Arachnids | Insects | Seeds |
|------|--------------------|--------------------------|-----------|---------|-------|
| AP   | 15                 | 0.124878                 | 0.4       | 111.2   | 0.7   |
| PM   | 50                 | 0.081881                 | 0.0       | 211.8   | 0.3   |
| MU   | 20                 | 0.089066                 | 0.2       | 95.8    | 0.0   |
| CA   | 35                 | 0.157727                 | 0.6       | 264.4   | 1.2   |
| UJ   | 20                 | 0.196816                 | 0.4       | 87.7    | 0.3   |
| PDa  | 15                 | 0.082933                 | 0.1       | 51.4    | 0.3   |
| PDb  | 20                 | 0.099196                 | 0.5       | 199.2   | 1.2   |

**Table 2**  
Details of GLMs. Estimates (+/– sd) and Anova 2 significance values have been noted. LGI = Landscape greening index.

|              | df | Arachnids      |         | Insects       |         | Seeds         |         |
|--------------|----|----------------|---------|---------------|---------|---------------|---------|
|              |    | estimate (sd)  | p-value | estimate (sd) | p-value | estimate (sd) | p-value |
| Height       | 1  | –0.18 (0.08)   | 0.45    | –0.01 (0.001) | <0.001  | –0.09 (0.03)  | 0.38    |
| LGI          | 1  | –22.12 (13.68) | 0.01    | –10.49 (0.52) | <0.001  | –20.69 (849)  | 0.11    |
| Height x LGI | 1  | 1.41 (0.63)    | 0.006   | 0.48 (0.02)   | <0.001  | 0.99 (0.30)   | <0.001  |

Surprisingly, the Arachnid group was poorly represented, with only 26 individuals of small species. Spiders are highly abundant in urban green spaces such as urban parks (Varet et al., 2013; Vergnes et al., 2014) or domestic gardens (Balkenhol et al., 1991; Vergnes et al., 2012). They are also abundant in high perched habitats such as green roofs (Madre et al., 2013) and walls (Madre et al., 2015). Many spiders are able to disperse via air by secretion of a silk balloon and can disperse tens of kilometers at many hundred meters of altitude, which is much higher than our sampling height (Bell et al., 2005). The low spider numbers raises the question of whether the trap type is appropriate for the taxa targeted.

With a mean of 158.6 insects per plate per 100 days in spring and 129.2 in autumn, the insects were the most abundant taxa collected (see Appendix B). The orders of Diptera (especially with gnats and mosquitos) and the Hemiptera (especially with aphids) were the more numerous and represented at least the half of the insect captures. Kadas (2006) observed high numbers of aphids on green roofs. Other groups were commonly noted such as Coleoptera and Hymenoptera. Those groups are highly abundant in Paris green spaces (Madre, 2014; Vergnes et al., 2014) and even on walls (Madre et al., 2015; Qiu et al., 2016). Those four orders of insects are also the most caught by Chapman et al. (2004) who used a flying net located at 200 m high and in a more natural landscape. Except for Diptera, these proportions are close to what Madre et al. (2013) observed on 113 green roofs located between a few to dozens of meters high in the north of France.

Seeds were underrepresented (less than 2 seeds per 100 days and per plate). The most caught Families in were the Asteraceae (e.g. Senecio and Chondrilla) and Betulaceae (e.g. Betula), but we also identified some seeds of Poaceae, Crassulaceae, Platanaceae, Portulacaceae, Paulowniaceae, Valerianaceae and Onagraceae. We have not found other publications that examine these plant families in urban aerial plankton. Seed dispersal is known to be dependent on seed characteristics (mass, morphology...) and weather (wind velocity and surface heating) but also with height of structures, such as vegetation in rural areas (Soons et al., 2004). In urban contexts the height of buildings could be a determinant of seed movement but the strong effect of vehicle airflow has been also shown to be an important factor of seed dispersal in roads and streets (Kowarik and von der Lippe, 2011; von der Lippe et al., 2013).

The analysis of site characteristics showed a significant interaction between height and Landscape greening index (Table 2). At high heights, Landscape Greening Index showed a strong positive effect on abundances for spiders, insects and seeds; at low heights, this effect is lesser and rather opposite (fig. 2). This result could be explained by a barrier effect of buildings that limits the dispersion

from potential sources of aerial plankton. At high heights, buildings are rarer and thus aerial plankton can disperse more easily through air currents.

In conclusion, aerial plankton is observed not only in high-altitude migration (Chapman et al., 2004, 2011) but also at low-altitude involving foraging flights and passive dispersal of insects even in towns. Air dispersal could be an important means of habitat colonization of the isolated habitats in urban landscapes (e.g., downtown) and especially those associated with buildings such as roofs (Bates et al., 2013; Madre et al., 2013). This kind of process needs to be more widely studied and should be incorporated in ecological urban planning (Łopucki and Kiersztyn, 2015).

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## Appendix A. The choice of the capture design

In order to choose a tool of capture of aerial plankton, we have tested several materials As we focused more on small species (micro arthropods, small seeds...) than on pollens or bacteria, we have tested several plates coated with a sticky material. Size A3 Plexiglas plates or wire meshes were tested in situation with different fats, black soaps and sticky papers After a first trial period, we selected a set of 4 plates with Plexiglas plate and wire screen (1 mm mesh) which was tested in June 2014 simultaneously on 5 buildings (hung on guardrails without walls behind) for three weeks. The wire mesh with black soap was quickly abandoned due to its poor resistance to weathering and lack of adhesion after a few days.

The results reflected both the holding and management boards and the number of bonded items shown the superiority of grilling plates with grease (Table 1) in terms of quantity but also collected propagules diversity 52% of total insects have been trapped by the wire mesh with fat and 65% of the seeds have been by the same device. This is explained by the fact that the grid system opposes a low wind resistance and therefore less likely to deflect the airflow loaded insects. Additionally, fat retains its adhesive properties throughout the sampling period

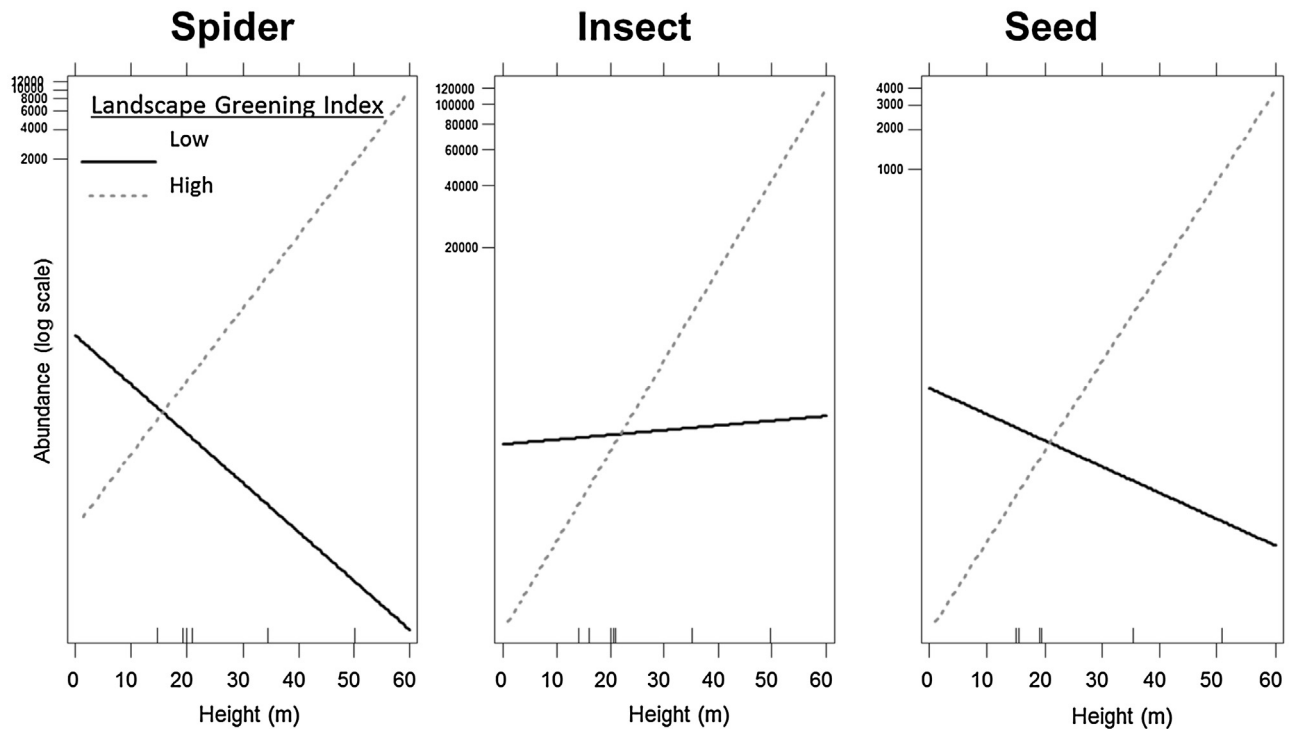


Fig. 2. Effect display of the interaction between Landscape Greening Index and height.

|                           | Insects | Arachnids | Seeds |
|---------------------------|---------|-----------|-------|
| Plexiglas plates with fat | 1409    | 3         | 7     |
| Sticky papers             | 405     | 0         | 6     |
| Wire meshes with fat      | 2274    | 7         | 24    |

Results of trapping tests for aerial plankton with different tools of similar surface during 3 weeks in 5 sites.

#### Appendix B. The list of orders, suborders and/or families of identified insects

Coleoptera Coccinellidae  
 Coleoptera Staphylinidae  
 Diptera Brachycera  
 Diptera Nematocera  
 Hemiptera Homoptera  
 Hemiptera Heteroptera  
 Hemiptera Aphadoidea  
 Hymenoptera Apoidea  
 Hymenoptera Formicidae  
 Psocoptera  
 Strepsiptera  
 Trichoptera  
 Thysanoptera

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