Occurrence, spatial distribution and succession of plants in contaminated sediments in urban stormwater basins

Détermination, distribution spatiale et évolution dans le temps des plantes sur des sédiments contaminés de bassins d'infiltration urbains

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RÉSUMÉ

Nous avons identifié sur 10 ans l'évolution de la flore en regardant la richesse et l'abondance des espèces dominantes sur deux types de bassins végétalisés: Minerve où la végétation a été planté volontairement, l'autre qui s'est naturellement colonisé (appelé Django). Pour Minerve, nous avons observé un gradient de l'amont (près de l'entrée de l'eau) à l'aval (partie la plus éloignée de l'entrée de l'eau) pour les paramètres comme la teneur en matière organique, la hauteur de sédiment déposé et les teneurs en éléments traces. Pour Django, la distribution est moins claire, mais nous avons aussi observé des zones avec des contenus contrastées en matière organique et en métaux lourds. La régression de la communauté des hélophytes sur Minerve au profit d'espèces rudérales pionnières marque l'évolution de ce site. Depuis 1999, plus de 93% des espèces implantées ont disparu, mais la diversité des hélophytes semble s'être stabilisée depuis 2008 avec seulement 12,5% de la variation du nombre de ces espèces. Sur le bassin de Django, le nombre d'espèces est resté stable depuis 2008. Mais la diminution de près de 50% du taux de recouvrement des macrophytes, réduit à *Phalaris arundinacea*, *Typha latifolia* et *Schoenoplectus tabernamontanii*, souligne un changement des débits d'eau entrants. La flore dominante trouvée dans des bassins d'infiltration évolue donc au fil du temps avec des espèces euryéces de pseudo-métallophytes des macrophytes (*Typha latifolia*, *Phragmites australis*, *Iris pseudacorus*, *Phalaris arundincea*), des espèces rudérales typiques des prairies sèches (Asteraceae, Poaceae, Brassicacées) et des espèces des zones humides (*Rumex* sp.). Avant tout, ces plantes sont principalement divisés/distribuée dans les bassins en fonction de facteurs hydrologiques, à savoir la disponibilité de l'eau.

ABSTRACT

We identified over a decade the evolution of species richness of flora and its abundance on two types of vegetated basins: Minerve where the vegetation was originally planted, and the other naturally colonized (called Django). In Minerve, we observed a gradient from upstream (near the water entry) to downstream (farthest from this water entry) for parameters like organic content, height of layer and trace element contents. In Django, the distribution is less clear, but we also observed zones with contrasting contents in organic matter and heavy metal. The regression of helophytes communities on Minerve for the benefit of ruderals pioneer species marks the evolution of the site. Since 1999, over 93% of implanted species have disappeared, but the diversity of helophytes seems to have stabilized since 2008 with only 12.5% of variation for the number of such species. On the basin of Django, the number of species remained stable since 2008. But, the decrease of almost 50% of macrophytes recovery rate, reduced to *Phalaris arundinacea, Typha latifolia* and *Schoenoplectus tabernamontanii*, emphasizes a change in entering water flow rates. The dominant flora found in infiltration basins evolves over time with euryece species of pseudo-metallophytes macrophyte group (*Typha latifolia, Phragmites australis, Iris pseudacorus, Phalaris arundincea*), ruderal species typical of dry grasslands (Asteraceae, Poaceae, Brassicaceae) and wetland species (*Rumex* sp.). But before all, these plants are mainly divided/distributed in theses basins according to hydrological factors, *i.e.* water availability among others.

KEYWORDS

Infiltration basin, temporal evolution, hydrological factors, helophytes, dominant vegetation

1 INTRODUCTION

Rainwaters, which run off over urban surfaces, are collected in basins and loaded with various pollutants such as pesticides and heavy metals (Moura, 2008; Winiarski *et al.*, 2006; Deschene, 2004). Furthermore, these waters are characterized by a high content of suspended solids and organic matter that will form a sediment layer at the soil surface (Deschene, 2004; Le Coustumer, 2008; Gonzalez-Merchan, 2012). These basins and their sediments are colonized by vegetation, either artificial or natural (Saulais, 2011; Bedell *et al.*, 2013). Indeed, the type of vegetation that is taking place in such environment depends on biotic and abiotic conditions as: access to light, oxygenation of the environment, availability of water and nutrients (Saulais, 2011). In the past, studies on the infiltration basins have shown that the spatial distribution of the vegetation was mainly impacted by three factors: the water content of sediments (Bedell *et al.*, 2013), the sediment thickness (Bedell *et al.,* 2013) and pollutant contents (Desjardins *et al.*, 2014). As part of this work, we identified over a decade the evolution of species richness of flora and its abundance on two types of vegetated basins: one where the vegetation was originally planted and grown (maintenance), the other naturally colonized with no maintenance. From these observations, we tried to establish the temporal and spatial evolution of the vegetation at the scale of the basin and to identify the factors that might explain this trend.

2 MATERIALS AND METHODS

2.1 Site location

Two infiltration basins ("Minerve" and "Django") in the Lyon area were studied. These basins has been monitored over the last decade in the context of long term survey developed by the OTHU (Field Observatory for Urban water Management- www.othu.org).The "Minerve" basin collects rainwater from a catchment area with tertiary activity. Its vegetation is artificial and had been implemented at the beginning of the activity of the basin. The mowing and clippings are regular. Conversely, the basin "Django" presents a spontaneous and natural vegetation, without any maintenance. It receives stormwater from an industrial area.

2.2 Sampling of flora and sediments

The physicochemical measurement and floristic surveys were conducted from March to May 2015. Thus, 12 quadrats (Django) and 10 quadrats (Minerve), each of 1m² in area, and were positioned on the sites according to vegetation patches observed. For each quadrat, the number of species and their percentage coverage were noted. An abundance index was calculated for each species using the method of Braun-Blanquet (Wikum and Shanholtzer, 1978). Data in 2015 were compared with the data obtained earlier in 1999 to Minerve and again in 2008 for the two basins (Saulais, 2011). The sediment of each quadrat for each basin was sampled to measure water content, the height of sediment layer, pH, organic matter and finally heavy metal content (Roullier and al., 1994).

2.3 Statistical results

The processing of data are carried out using R© software. The normality test and Shapiro Wilk test revealed a part of the measured parameters could not be considered as normal distributions. As a result, the non-parametric Kruskal Wallis had to be considered for the tests of hypotheses. The significance of the results is assessed considering a threshold 0.05 for the p-value.

3 RESULTS

3.1 Sediment

High contents of organic matter (18% to 39%) and heavy metal (Zn Django: 1350 mg/mg MS to 2770 mg/mg MS) are observed in samples. In Minerve, we observed a gradient from upstream (near the water entry) to downstream (farthest from this water entry) for parameters like organic, height of layer and trace element contents. In Django, the distribution is less clear than for Minerve, but we also observed zones with contrasting contents in organic matter and heavy metal. The highest contents were observed as a function of water localization at the surface and/or height of sediment deposit.

3.2 Abundance and species richness

For Minerve basin, the floristic surveys from 1999 and 2008 have shown a drastic decline in species richness (Saulais, 2011) (Figure 1a, 1b). Most plants covering the basin were macrophytes species. In 2015, the basin includes 18 species (Figure 1c). Wetland zones are dominated by *Acorus calamus, Typha latifolia, Iris speudacorus* and *Phragmites australis* associated with other rare species helophytes: *Schoenoplectus tabernaemontani, Solanum dulcamara* and *Phalaris arundinacea*. However, dry grasslands appeared at the western end of the basin (farthest from water entry) and are covered by Asteraceae (including mainly *Solidago canadensis*), *Geranium dissectum, Cardamine hirsuta, Rumex obtusifolius* and *Poa* sp. This grassland area allows the development of a covered dense Asteraceae (Figure 1).

For Django, after the basin rehabilitation in 2002, no vegetation was sown or planted (Figure 2a). Six years later (2008), the inventories have highlighted a separate organization of vegetation including 58 species (Saulais, 2011) (Figure 2b). Distinct vegetation groups emerge and reflect mainly 3 types of contrasting ecological environments: disturbed environments, dry and stony zones (*Senecio inaequidens, Capsella bursa pastoris, Cardamine hirsuta*), wetland zones with vegetation subjected to cycles of flooding and drying up (*Phalaris arundinaceae, Polygonum mite, Galium aparine*) and areas regularly submerged by water (*Typha latifolia, Eleocharis palustris*) (Saulais, 2011). In 2015, the floristic survey shows a relative stability in species richness (57 species with most of them being unchanged) (Figure 2c). The three distinct ecological environments are always present but with different recovery rates. The wetland zone is dominated by *Phalaris arundinacea* and *Typha latifolia*, associated with other rare helophytes: Cyperaceae and *Solanum dulcamara*. An "intermediate" zone sporadically flooded is covered mostly with *Rumex* sp. This Polygonaceae belt defines the boundary between the wetland and the rest of the basin flooded only during intense rainfall events. Many Asteraceae, Brassicaceae, Poaceae and Lamiaceae characterize the driest areas (Figure 2).

4 DISCUSSION

The regression of helophytes communities on Minerve for the benefit of ruderals pioneer species marks the evolution of the site. The appearance of a separate grassland area from the wetland is the result of such regression. Since 1999, over 93% of implanted species have disappeared. In contrast, the diversity of helophytes seems to have stabilized since 2008: in 7 years, the number of species varied only by 12.5%.

On the basin of Django, the number of species remained stable since 2008. In addition, the decrease of almost 50% of macrophytes recovery rate, reduced to *Phalaris arundinacea, Typha latifolia* and *Schoenoplectus tabernamontanii*, emphasizes a change in entering water flow rates. The installation and maintenance of the species *Acorus Calamus, Iris pseudacorus, Phalaris arundinacea, Phragmites australis* and *Typha latifolia* is not surprising because these helophytes have a very broad ecological valence (IBMR Standard AFNOR, 2004). They support also any type of environment: oligotrophic to eutrophic and those contaminated with organic and inorganic pollutants (IBMR Standard AFNOR, 2004). They can be well described as pseudo-metallophytes (Remon, 2009). The pathways of the water at surface seems to have changed over time in the two infiltration basins. In Minerve, water and sediments accumulate preferentially at the base of the bridge, but the eastern end of the basin is always ponded with water. Due to such water ponding, the helophytes (*Iris pseudacorus, Typha latifolia*) are able to remain in this zone. A resurgence of *Phalaris arundinaceae* (reduced to a few individuals in 2008) was also observed, which may reveal a natural recolonization of the basin (these species tolerate both alkaline and acid soils). In contrast, the presence of a "dry" area and a wetland highlights a chronic drought episode in Minerve basin. Pioneering grassland species such as Asteraceae, have undoubtedly benefited from the decline of Iridaceae, following the reduction of soil water content. Over time, a steady decline in the number of *Iris pseudacorus* could be observed. In Django, vegetation also seems to follow stormwater pathways. The helophyte vegetation seems to have moved and been replaced by grassland vegetation. In 2008, 20% of the surface of the basin was naked (Saulais, 2011), whereas today it is only 6%. The increase on sediment deposit at the surface as well as most water availability in several zones can explain the increase of the surface vegetalized. The pioneer vegetation of meadows, typical of dry and rocky areas, may have colonized the area.

5 CONCLUSION

The dominant flora found in infiltration basins evolves over time. It brings together euryece species of pseudo-metallophytes macrophyte group (*Typha latifolia*, *Phragmites australis*, *Iris pseudacorus*, *Phalaris arundincea*), ruderal species typical of dry grasslands (Asteraceae, Poaceae, Brassicaceae) and wetland species (*Rumex* sp.). They can be classified for most of them as helophytes with a very broad ecological valence. Indeed, they support very well any type of environment: oligotrophic to eutrophic and environments with highs loads of organic and inorganic pollutants, which is one of the reason why these are referred to as pseudo-metallophytes. But before all, these plants are mainly divided/distributed in theses basins according to hydrological factors, *i.e.* water availability among others.

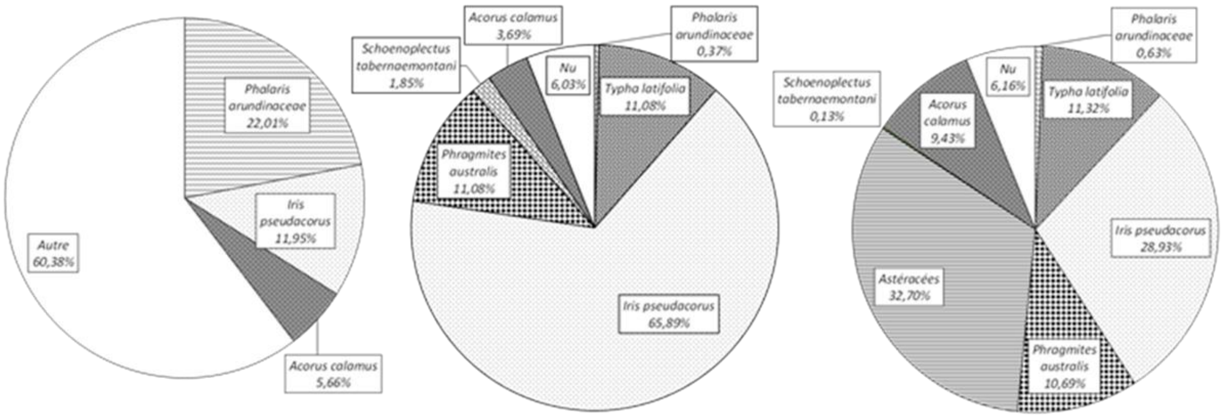

Figure 1a: year 1999 Figure 1b: year 2008 Figure 1c: year 2015

Figure 1 : Recovery rate of the dominant vegetation on the Minerve infiltration basin over the time.

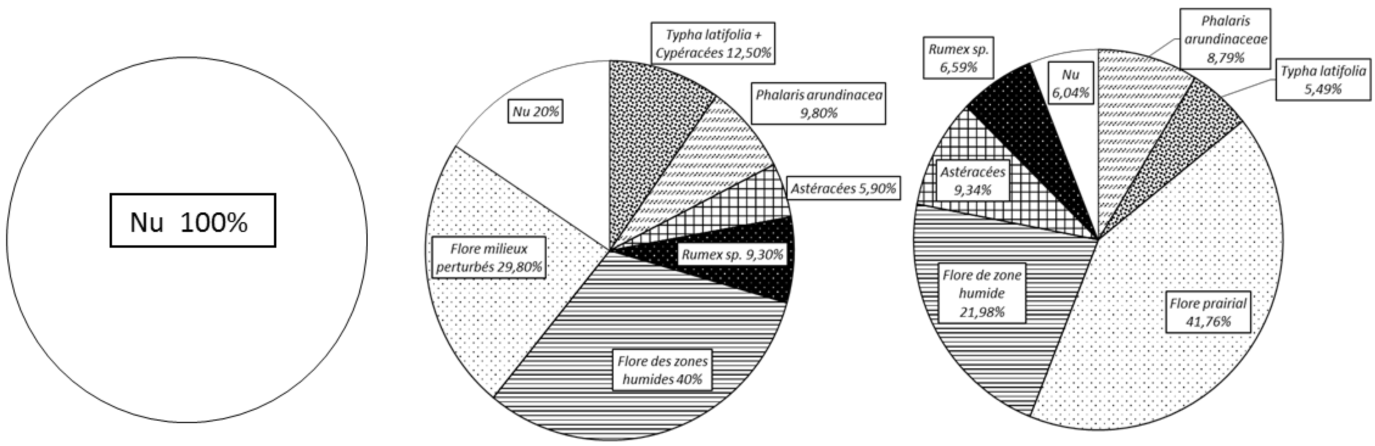

Figure 2a : year 2002 Figure 2b : year 2008 Figure 2c : year 2015

Figure 2 : Recovery rate of the dominant vegetation on the Django infiltration basin over the time.

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