



Do railway edges provide functional connectivity for plant communities in an urban context?

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ABSTRACT

Functional connectivity is essential to maintaining biodiversity in fragmented landscapes but little attention has been given to structures that can provide it in an urban context. Using both the taxonomic and functional diversity of semi-natural grassland plant communities, we assessed the functional connectivity of linear transportation infrastructures in urban landscape. We sampled the vegetation at 71 study sites located along the edges of two railway lines. We hypothesised that if railways favour functional connectivity, then spatially connected communities should be more similar than disconnected communities. Therefore, we compared floristic dissimilarities between site pairs that were either connected or separated by a railway spatial break (overpass or station). As a further approach, we supposed that functional connectivity may attenuate the effect of urbanisation filters on plant communities. Thus we examined whether and how edges' plant communities were influenced by urbanisation and compared our results to the patterns described in the literature. Functional connectivity was mainly maintained at railway stations, contrary to overpasses, which seemed to interrupt dispersal, demonstrating that railway edges provide connectivity for some but not all functional groups: this was only true for moderately mobile species. Surprisingly, railway edges did not seem to play an additional connective function for invasive species, the presence of which being strongly related to the urbanisation intensity and not influenced by spatial breaks along railways. Our study thus highlights the potential function of railway edges as corridors for common grassland plants. Landscape managers should include railways in green networks to improve connectivity in urban landscapes.

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1. Introduction

Habitat fragmentation is considered a severe local, regional and global perturbation that affects biotic communities (Debinski and Holt, 2000; Fahrig, 2003). Fragmented landscapes are characterised by small patches that are isolated from each other by a matrix that acts as a selective filter for species movement (Lawton, 1999; Wilcove et al., 1986). In such landscapes, connectivity is considered a key issue for biodiversity conservation (Taylor et al., 1993; Wehling and Diekmann, 2009). Therefore, it is of great importance to identify connectivity and the spatial arrangements of habitat patches providing it (i.e. corridors or stepping stones) to assist with the decisions of conservation practitioners regarding landscape management. Through habitat loss and isolation, fragmentation affects community richness, composition and species interactions (Fahrig, 2003). A species' vulnerability to fragmentation varies among functional species traits: dispersal abilities and species mobility are considered key traits for explaining species responses

to fragmentation (see review by Ewers and Didham (2006) and Schleicher et al. (2011)), and they can be used to identify connectivity in linear habitat patches. As illustrated by Doerr et al. (2011), structural connectivity is a component of functional connectivity; an interruption of the first should result in an interruption of the second, thus having an effect on less mobile species. In our study, we used this assumption as an indirect method to test functional connectivity in linear patches.

In habitat patches, plant composition is determined by biotic and abiotic filters (Knapp et al., 2008a; Zobel, 1997) that select species with suitable functional traits from a species pool through dispersal and survival (Roy and de Blois, 2006; Williams et al., 2009). The effects of these filters on taxonomic and functional communities are particularly strong in urban landscapes, where small and isolated patches of habitat (e.g. private or public gardens) are situated within a human dominated matrix (Stenhouse, 2004). Urban filters are, in part, linked to environmental conditions such as higher temperatures or higher nitrogen levels due to pollution (McDonnell et al., 1997; Pellissier et al., 2008) (hereafter environmental urbanisation effects). Human preferences also act as filters causing species gain (mainly of exotic species) and losses

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(Williams et al., 2009). Other urban filters, such as habitat size or dispersal barriers, are due to fragmentation and isolation (Grimm et al., 2008) (structural urbanisation effects), and their effects on biotic communities should be attenuated by connectivity (Tewksbury et al., 2002). If linear patches provide structural connectivity, an attenuation of these urbanisation effects on taxonomic and functional plant communities should be observed when compared with the urbanisation effects described in the literature. We used this assumption as a supplementary approach to assess functional connectivity in railway edges. Although urban landscapes are strongly fragmented (Stenhouse, 2004), connectivity has been poorly studied in this context (but see Kowarik and von der Lippe, 2011; Schleicher et al., 2011). Transportation networks are mainly considered to be barriers for connectivity (Jackson and Fahrig, 2011) or corridors for invasive species (Brown et al., 2006). However, in urban landscapes, railways ensure structural connectivity (Calabrese and Fagan, 2004) because their vegetated edges penetrate into dense urban areas, similarly to rivers or to some roads. Despite their potential for connectivity in an anthropogenic context, their functional connectivity has been poorly studied (but see Tikka et al., 2001), and most studies focus on invasive species (Hansen and Cleverger, 2005).

In the present study, we analyse the potential connectivity of railway edges for plant communities in an urban context. We hypothesise that if railway edges favour connectivity, spatially connected communities within railway edges should be more similar than disconnected communities. Railway structural connectivity is regularly interrupted by spatial breaks, such as overpasses and stations. We therefore assumed that although railway edges provide functional connectivity, they can be disrupted by railway breaks. We tested this assumption by comparing floristic dissimilarities between sites located along railway edges that were either connected or separated by a railway break, this comparison was done for different functional species traits. As a supplementary approach, in order to discuss the results that we obtained, we hypothesised that if railway edges favour connectivity this should attenuate the effect of urbanisation filters (those due to fragmentation and isolation) on plant communities. We thus examined the effect of urbanisation intensity on species richness, diversity and trait composition, and we compared our results with the patterns described in literature.

2. Materials and methods

2.1. Study sites and data collection

The study was conducted along two long-established railway lines (built in 1840 and 1847) in the south of the Parisian region, France (Fig. 1). This region is densely populated, with 20% of the national population living in just 2% of the nation's land area. The two lines traverse a landscape structured by different degrees of urbanisation, as they cross numerous cities and towns from the south of the region towards the centre of Paris. The vegetation found along the borders of the train tracks is mainly spontaneous as the edges have not been planted or sown since their construction and is principally interrupted by railway stations and overpasses. The study sites were all mown approximately at the same time during the summer, 2 years before the study (SNCF, French National Railways, personal communication).

As we wanted to test the effect of railway continuity and landscape urbanisation on railway plant communities, sites were chosen to minimise variations in other environmental variables and to be isolated from other habitat patches. Thus, we tried to standardise sites using aerial photographs and field surveys. All sites were selected with the following two characteristics: (1) they were

bordered by the same environment: on one side ballast (crushed rock) and rails, and on the other side a small paved road (or a parking lot) and dwellings; (2) they exhibited the same features: grassland vegetation less than 1 m in height and similar border width and slope (Fig. 1). Note that ballast was treated twice a year with a non-selective herbicide for safety reasons, therefore there were almost no plants growing in ballast. This practice cannot be changed at the moment because there are not economic alternative solutions (SNCF, personal communication). Based on these criteria, we identified 71 study sites along the two lines (n1 and n2, respectively) located between 70 and 4 km from the centre of Paris. Each site consisted of a 4- to 8-m-wide (6 ± 1.4 s.d.) grassy embankment that was at least 50 m from the nearest large tree. The distance between two consecutive sites varied between 0.2 and 25 km, with an average distance of 3.3 km. Within the centre of each site, we established a 50 m-long transect 4 m from the rails, and we inventoried all vascular plants in five sample quadrates (1 m²) distributed every 10 m. All taxa, except *Taraxacum*, were identified to the species level according to the French Flora Index (Kerguélen, 2003) and the International Plant Names Index (IPNI, 2008). In order to check for potential soil differences between sites, we measured soil pH, texture, colour, compaction, and stoniness.

2.2. Spatial breaks and urbanisation measure

Using the French railway company database (personal communication), aerial photographs and field observations, we identified and located the two main kinds of spatial breaks in vegetation connectivity: railway stations and overpasses (main length $12.2 \text{ m} \pm 21$ s.d.). To take into account the effects of urbanisation on plant communities, we defined a circular 200 m-wide buffer (which radius has been shown to be appropriate for flora studies (Muratet et al., 2007)) around each site using GIS (ARCGIS 9.3/ESRI). Then we determined the areas of the main land cover types (woodland, farmland, urban) in the surrounding landscape of each site using a detailed, regional geo-referenced land use database of landscape features (IAURIF, 2003). Urban cover was defined as the proportion of built and paved surfaces and it varied between 26.8% and 82.5% (55.3 ± 18.3 s.d.), with the lowest values corresponding to higher proportions of woodland (mean 19.5 ± 18.7); farmland habitat was scarce along our study lines (mean 1.0 ± 2.9 s.d.). Note that our study sites were located in more or less densely urbanised areas but not in a complete gradient (i.e. varying from 0% to 100%) because sites were chosen with the aim to minimise the variation of environmental covariables. Indeed, at a finer scale, within a 50 m-wide buffer, urban cover was high and similar across sites (mean $89\% \pm 15$ s.d.), which confirmed that we chose sites with a similar configuration.

2.3. Species functional traits and species mobility

To assess the influence of railway spatial breaks on community functional composition, species were characterised by their functional traits. Data were mainly taken from the Bioflor database (Klotz et al., 2002), LEDA traitbase (Kleyer et al., 2008) and from literature reviews (Appendix A). Some traits were grouped to minimise bias due to rare classes: myrmecochory was included in epizoochory, and autochory and barochory were merged. Chi-square tests among traits were computed to select uncorrelated traits. We retained floristic status (exotic), invasiveness (subgroup of exotic), and dispersal traits as follows: pollen vector (wind, insect, selfing); reproduction (seed, mixed seed and vegetative); and dispersal mode (anemochory, barochory, zoochory (endozoochory, epizoochory)).

As connectivity is also related to species mobility (Ewers and Didham, 2006; Matlack and Monde, 2004; Ockinger et al., 2010),

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