



Green corridors in urban landscapes affect the arthropod communities of domestic gardens

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ABSTRACT

Ecological corridors are landscape elements that prevent the negative effects of fragmentation. However, their effectiveness has never been clearly validated in urban landscapes.

We analysed the role of green corridors in an urban context by comparing metacommunities of arthropods in (i) woodlots considered as sources of species, (ii) woody corridors and domestic gardens that are (iii) connected (CG) or (iv) disconnected to corridors (DG) and taking into account the connectivity of the matrix. We trapped 3 taxa of arthropods – spiders, carabids and staphylinids – because they are sensitive to fragmentation but with different dispersal capabilities. We analysed their species richness, abundance and taxonomic and functional composition.

For the 3 taxa, the taxonomic and functional compositions of communities in CG were closer to those of the corridor and the source than those of DG. Woodland species were associated with source, corridor and CG. A lower abundance in DG was revealed for staphylinids and spiders. Lower species richness in DG was observed for staphylinids.

The differences between taxa could be explained by the dispersal capabilities of the species and by their various responses to landscape structures. For carabids, processes at a wider scale could be responsible for their rarity in sources and, consequently, in gardens. For spiders, the colonisation from other sources could explain the high species richness found in disconnected gardens.

Our results suggest that the role of corridors is crucial for enhancing biodiversity in green spaces such as domestic gardens. Our results clarify the effectiveness of corridors in urban landscapes and have direct implications for the ecological management of cities.

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1. Introduction

In urban landscapes, fragmentation, usually considered as a major threat to biodiversity, dramatically affects landscape structure and decreases landscape connectivity (Hamer and McDonnell, 2008; McGarigal and Cushman, 2002; McKinney, 2008; Pauchard et al., 2006). Generally, the remaining woodland habitats in cities, called green spaces (Smith et al., 2006a), are physically distant from each other and are isolated by a hostile matrix composed of buildings and streets (Collinge, 1996; Gibb and Hochuli, 2002). Thus, fragmentation limits the dispersal of many species and strongly shaped metacommunities sensu (Wilson, 1992), i.e. potentially interacting species linking via dispersal (Hubbell, 1997; Leibold et al., 2004; McKinney, 2006; Rosindell et al., 2011).

Indeed, in more natural landscapes, ecological corridors are an effective strategy to limit biodiversity decline within fragmented woodland habitats (Bailey, 2007; Gilbert-Norton et al., 2010). Consequently, the protection of corridors and green frameworks is a

major objective of landscape management policies (Jongman et al., 2004). In urban landscapes, the development of woody corridors could be an interesting way to limit fragmentation and enhance “ordinary biodiversity” as desired by citizens (Ahern, 2007; Blair and Johnson, 2008; Savard et al., 2000). In fact, matrix properties and the use of corridors in cities are different than in more natural landscapes, and previous results cannot be easily applied in urban areas. The effects of ecological corridors in an urban context need to be properly tested (Clergeau, 2007; Gilbert-Norton et al., 2010).

The aim of this study is to assess the effectiveness of corridors in suburban landscapes using arthropod metacommunities of urban domestic gardens. Although domestic gardens are small in area, they are numerous, and they represent a significant proportion of green space area in cities (Goddard et al., 2010; Loram et al., 2007). The potential role of domestic gardens in urban conservation has been shown by recent studies (Davies et al., 2009; Loram et al., 2007). However, the mechanisms responsible for the structure of communities in gardens have not been clearly identified.

It is urgent to better understand the importance of dispersal in the structuring of communities and, thus, in the functioning of

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metacommunities (Holyoak et al., 2005). To this aim, a comparison of community responses to landscape structure using different taxa with different dispersal behaviours should be meaningful (Fattorini, 2011; Le Viol et al., 2008; Schweiger et al., 2005). Thus, we focused our study on 3 major taxa of arthropods: spiders, carabids and staphylinids (Didham et al., 2010; McIntyre et al., 2001). As these species vary in preferences for habitat and in dispersal capabilities, the community properties of these three taxa are indicative of both local and landscape modifications. Some carabids (Chapman et al., 2005; Joyce et al., 1999) and staphylinids (Markgraf and Basedow, 2002; Tomlin et al., 1992) were able to disperse several kilometres by flying and some spider species up to tens of kilometres using their silk (Bell et al., 2005). Some species (mainly woodland species for carabids and staphylinids), were ground dwelling and thus are extremely sensitive to physical barriers such as road or buildings (Desender et al., 2005; Mader et al., 1990). Moreover, they are located at an intermediate level on food webs: as predators of smaller arthropods (Good and Giller, 1991; Griffiths et al., 2007; Nyffeler and Sunderland, 2003) and prey for vertebrates (Deichsel, 2006; Thomas et al., 2001) and thus have a major ecological function.

To analyse the effectiveness of corridors, we compared the richness, abundance, taxonomic and functional composition of metacommunities in woodlots considered as a source, woody corridors linked to the sources, and hedgerows of two types of gardens – disconnected from (DG) or connected (CG) – to the corridor. We then focused our analyses on gardens to control for effects of local variables and landscape variables. As the measure of landscape connectivity should not be limited to corridors (Gaublomme et al., 2008; Lizée et al., 2011; Prevedello and Vieira, 2010), we also took into account the properties of the matrix surrounding the gardens.

2. Materials and methods

2.1. Study area and sampling design

To test the effectiveness of woody corridors in gardens within urban matrices, we defined a strict sampling design at four urban

sites (s01 to s04) located around Paris (see Fig. 1). The four sites have been selected regarding to their landscape configuration. Indeed, each site was composed of an urban matrix composed of a mosaic of roads and small detached houses with domestic gardens, a unique urban woodlot (park or wood up to 150 ha) in a 1.5 km radius that was potentially the only source for arthropods (Chave, 2004), to avoid the effect of uncontrolled potential sources of arthropods, and a woody corridor (between 20 and 50 m wide) (Davies and Pullin, 2007).

Within each urban matrix, we selected two types of gardens. First, we selected four connected gardens (CG) contiguous or less than 10 m from the corridor. Two CG were located between 20 and 300 m from the source and two were located between 500 m and 1 025 m. As a control (Gilbert-Norton et al., 2010), we also selected four gardens located more than 300 m from corridor and defined as disconnected gardens (DG). To avoid the correlation between the distance to source and the type of garden, we selected DG located at the same distance from sources. We also checked for correlation using Mann–Whitney test, $W = 377.5$, $p = 0.07$ and using site as a random effect in a generalised linear mixed models (Distance to woodlot \sim connection to corridor + site, $\beta = 0.07$ (SE = 0.22), $p = 0.73$).

In all sites, the dominant vegetation of the woodlots and corridors is mixed deciduous and is dominated by native oaks (*Quercus spp.*). The lower strata of vegetation are mainly composed of *Rubus fruticosus* and *Hedera sp.* All gardens have hedgerows.

Thus, we sampled metacommunities of arthropods simultaneously in four sources, four corridors, sixteen CG, and sixteen DG (Fig. 1).

Arthropods were sampled using pitfall traps of 8.5 cm wide in diameter, 10 cm deep and contained a non attractive preservative (ethylene glycol). They were settled with a minimum of 5 m between traps. At each site, we set one station of four traps within the source, three stations of three traps within the corridor. In gardens we only set one station of two traps under hedgerows as it was difficult to set more traps separated under hedgerows. A total of 116 traps were laid for this study. Arthropods were trapped continuously from May to July 2009 (all traps were emptied once after 3 weeks).

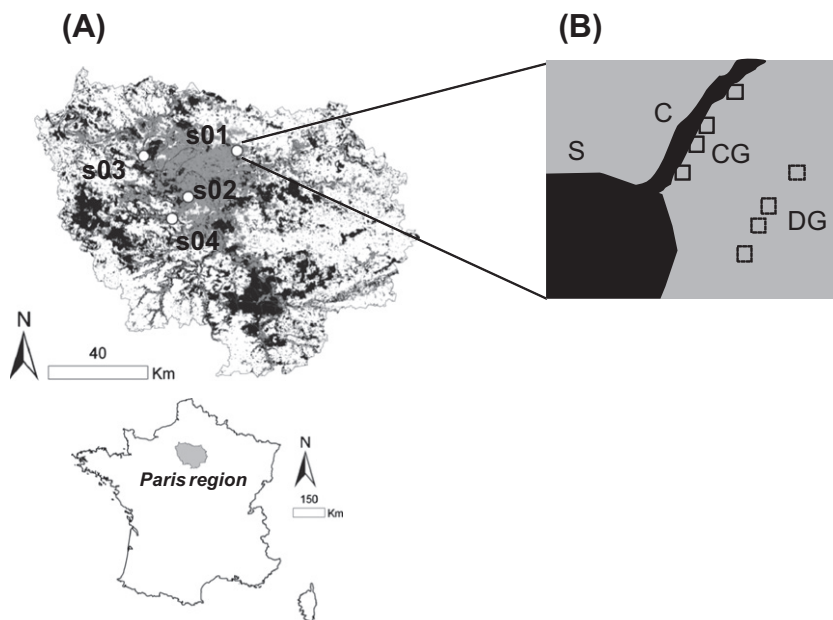


Fig. 1. Map of the Paris region showing urban sites (A) and schema of the sampling design (B) of a site. (A). Open and rural land cover are presented in white. Woodlands are represented in black. Urban cover is represented in grey. Sites are indicated by white circles (s01 to s04). (B) A site is composed of 4 green space types: a source (S), a corridor (C), 4 connected gardens (CG) and 4 disconnected gardens (DG).

2.2. Identification and species attributes

Adult arthropod species were identified using classical keys. As immature arthropods are difficult to identify, they were not considered in our analyses, and *Atheta* species (Family *Aleocharinae*, staphylinids) were considered as *Aleo. spp.*

We recorded two functional traits: dispersal mode and habitat affinity. We defined two classes for the dispersal mode: (1) non-aerial dispersal and (2) aerial dispersal. We also defined three classes for habitat affinity to woodlands: (1) specialist open land species and generalist species that are more abundant in open land habitats, (2) generalist species without habitat focus and (3) generalist species more abundant in woodland and specialist species of woodlands. For carabids and staphylinids, the classifications followed Deichsel (2006) and were completed respectively by Ribera et al. (2001) and through interviews with specialists (Tronquet, pers. com). For spiders, high dispersal capability correspond to aerial dispersal using silk, also known as ballooning and species listed in Bell et al. (2005) were considered as aerial dispersers. For spiders, habitat affinity was coded following Harvey et al. (2002) and completed by Entling et al. (2007). Details of traits are given in Supplementary Material 1.

2.3. Environmental variables

Within each site, we measured at the landscape scale, we measured the connection to the corridor (CG/DG) and the distance between garden and source (Dist) (Smith et al., 2006a). We also described the matrix surrounding gardens. From a normalised difference vegetation index (NDVI, resolution of 15 m, 11 classes of land uses), considered as a relevant descriptor of urban landscapes (Kerr and Ostrovsky, 2003; Yuan and Bauer, 2007), we considered three land use classes: build surface, gardens and woodlands. Using FRAGSTATS software (McGarigal, 2002), we characterised the composition and the configuration of the landscape surrounding each garden by calculating several metrics in a circular buffer of 200 m centred on gardens (excluding source and corridor). We measured four metrics for each of the three land use classes: percentage of the class in the buffer (per), patch density which measured the fragmentation (FRAG), area-weighted mean patch fractal dimension which measured the patch shape complexity (FRACTAL) and the aggregation index that measured the structural connectivity (AI). These twelve metrics were synthesised in a connectivity matrix index (CMI) using a PCA (coordinates of sites in axis 1, 54.84% of the total inertia) (Supplementary materials 3 for details).

At the local scale, we measured sixteen variables (vegetation cover, soil features, hedgerows, surfaces, and management (Supplementary material 2)). None of these variables were correlated to the type of garden (Supplementary materials 2). Using the same method than for matrix description, we tried to find a synthetic variable of the local scale but as in other studies on gardens, we failed (Smith et al., 2006a). Thus we retained the vegetation cover because it was correlated with many variables (Supplementary material 3). Moreover, vegetation cover is known to strongly affect arthropod composition in woody habitats (Magura et al., 2008; Small et al., 2006) and is an important feature of domestic gardens (Smith et al., 2006b). Note that vegetation cover under hedgerow (Veg) was described for a 4 × 4 m square around each trap and was classified into five categories (0–10; 11–25%, 26–50%, 51–75%, 76–100%).

2.4. Statistical analysis

We analysed the metacommunities of arthropods by considering three complementary approaches. First, we analysed species

richness (SR) and abundance (AB). Next, we made a more accurate analysis using taxonomic composition and finally, we analysed the functional composition of the metacommunities using habitat affinity and dispersion traits.

For each approach, we made two distinct analyses. First, we ran a global analysis comparing all types of green spaces. Second, we ran a specific analysis on gardens (hereafter called garden analysis) to verify the effects of the connection to the corridors, the CMI, the distance to the source, and accounting for vegetation cover (Gilbert-Norton et al., 2010). After measure of data and prior to garden analysis, we checked for relationship between all variables used in models (Supplementary material 2). To take into account the difference in sampling effort between the different types of green spaces, all analyses were computed at the trap level.

2.4.1. Species richness and abundance

The species richness and abundance of arthropods were analysed with generalised linear mixed models (GLMM) with a link log function and a Poisson error structure, relevant for count data (Bolker et al., 2009). According to the nested structure of our sampling design (stations within sites), we treated the site variable as a random effect (Noda, 2004), while the other explanatory variables were treated as fixed effects. We used a hypothesis approach for each step of analyses (Faraway, 2006). The analyses were computed with R 2.7.0 software and the lme4 package (Bates and Maechler, 2009).

2.4.2. Taxonomic and functional composition

We analysed the effect of corridor on the taxonomic and functional composition of the arthropods using a partial Redundancy Analysis (pRDA). pRDA is a constrained ordination method related to principal components analysis which allows community composition to be related to environmental variations (Legendre and Anderson, 1999). As a partial method, it can be used to remove the effect of covariables. In our case we used the geographical coordinates of sites (x_coord , y_corr) to correct for spatial correlation. For taxonomic composition analysis, data were transformed using the Hellinger distance to limit the weight of rare species and of the double – absence of species (Legendre and Gallagher, 2001).

Functional composition was handled using pRDA with the same covariable and a community weighted trait matrix as response variable (CWM) (Lavorel et al., 2008).

As pRDA was sensitive to rare species, we did not retain species observed once (singletons). ANOVA-like permutation tests ($n = 999$) were conducted to assess significance of the all analysis and for each term of the model.

3. Results

3.1. Species richness and abundance

Across the 4 sites, we captured 1262 adult individuals of spiders, 398 of carabids and 1446 of staphylinids, representing, respectively, 75, 25 and 61 species. The most abundant species were *Lepthyphantes flavipes* (23.14%), *Ozyptila praticola* (12.68%) and *Zodarion italicum* (6.10%) for spiders; *Nebria brevicollis* (22%), *Notiophilus rufipes* (25%) and *Harpalus atratus* (10%) for carabids; and *Aleo. spp.* (40%), *Anotylus inustus* (12%) and *Platarea brunnea* (10%) for staphylinids.

Using GLMM, we found an effect of the green space type for staphylinids and spiders. We observed lower species richness within the DG for staphylinids than within the other green spaces (sources, corridors and CG) and a lower abundance within the DG for staphylinids and spiders (Table 1).

Table 1

Generalised linear mixed models (GLMMs) showing the differences between sources and the other green space types in term of species richness (SR) and abundance (AB) using site as a random effect. For SR and AB, β and SE were transformed into mean species richness per trap and mean abundance with SE per trap using an exponential function, and significance levels were given (denoted * $p \leq 0.05$, ** $p \leq 0.001$, *** $p \leq 0.001$). Connected gardens (CG), Disconnected gardens (DG).

	Spiders		Carabids		Staphylinids	
	SR (SE)	AB (SE)	SR (SE)	AB (SE)	SR (SE)	AB (SE)
Sources	5.71 (1.24)	13.3 (1.31)	1.31 (1.38)	1.5 (1.84)	3.32 (1.3)	11.82 (1.47)
CG	4.94 (1.13)	10.96 (1.15)	1.58 (1.22)	2.19 (1.42)	3.32 (1.16)	11.16 (1.24)
DG	4.09 (1.14)	6.5 (1.16)	1.16 (1.24)	1.84 (1.43)	1.29 (1.21)***	3.87 (1.26)***
Corridors	4.52 (1.14)	9.33 (1.18)	1.25 (1.24)	1.68 (1.48)	3.03 (1.18)	11.14 (1.27)

For garden analysis, the abundance was significantly lower in the DG for spiders and staphylinids (respectively $\beta = -0.49$ (SE = 0.23), $p = 0.03$ and $\beta = -0.98$ (SE = 0.32), $p = 0.002$). Species richness was also significantly lower in DG for staphylinids ($\beta = -0.67$ (SE = 0.17), $p \leq 0.001$). The abundance of carabids significantly decreased with the distance to source ($\beta = -1.01$ (SE = 0.42), $p = 0.02$) and was affected by vegetation cover ($\beta = 1.52$ (SE = 0.4), $p \leq 0.001$). For carabids, we found a significant negative effect of distance to source ($\beta = -0.46$ (SE = 0.20), $p = 0.02$) and a positive effect of CMI on species richness.

3.2. Taxonomic composition

As shown by pRDA, corridors, sources, CG and DG supported significantly different metacommunity compositions of spiders, carabids and staphylinids ($p < 0.01$ for the 3 taxa). However, the metacommunities in the CG were close to the metacommunities of the corridors (Fig. 2). The garden analyses (Table 2 and Fig. S1) confirmed that the difference between CG and DG was mainly due to the connection with the corridor. CMI was significant for carabids and staphylinids whereas the distance to source was significant only for carabids.

The pRDA (Fig. 2) showed that the spider species *Diplocephalus picinus* (Diplopic) and *Diplostyla concolor* (Diplcon) were more associated with sources whereas *Trachyzelotes pedestris* (Traped), *Tenuiphantes flavipes* (Tenfla) and *Z. italicum* (Zodita) were associated with the corridors and CG. DG were associated with *Troxoch-*

rus scabriculus (Troxasca) and *Erigone dentipalpis* (Eriden). For carabids, we observed that *Abax parallelepipedus* (Abapar), *Calathus fuscipes* (Calruf) and *Pterostichus madidus* (Ptemad) were associated with sources whereas *N. brevicollis* (Nebbri), *Harpalus rufipes* (Har-ruf), *N. rufipes* (Notruf) were associated with the corridor and the CG. *H. atratus* (Haratrat) were the only species associated with DG. For staphylinids, we observed that *A. inustus* (Anoinu) and *Plataraea brunnea* (Platbru) were more associated with sources whereas *Anthobium atrocephalum* (Antatrat) and *Omalium rivulare* (Omariv) were associated with corridors and CG. *Aleo. spp* was the only species associated with DG.

The garden analysis confirmed the association between the previous species and the different garden type (Fig. S1).

3.3. Functional composition

For carabids, staphylinids and spiders, we found a significant relationship between species traits and environmental variables (Fig. 3) (respectively $p \leq 0.01$, $p \leq 0.01$ and $p \leq 0.05$). The green space type influenced the distribution of species according to their habitat affinity. For spiders, we observed that sources, characterised by a community with high affinity to woodlands, were separated from the CG, DG and corridors. For carabids and staphylinid, sources, corridors were at the extremity of a gradient representing the decrease of the affinity to woodland habitat and the increase of the dispersal capabilities. DG were at the other extremity of this gradient and were functionally characterised by

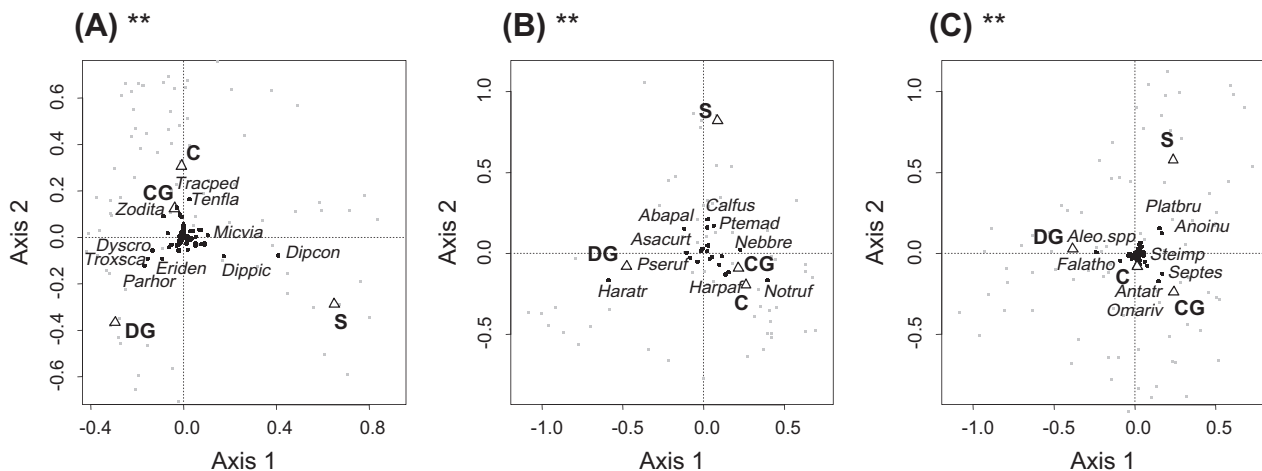


Fig. 2. Ordination diagram (biplot) from partial Redundancy analysis (pRDA) of spider (A), carabid (B) and staphylinid (C) metacommunities. For global analysis, we considered all type of green spaces (white triangle): source (S), corridor (C), connected garden (CG) and disconnected garden (DG). P values are represented for each axis and for each taxa (denoted ** $p \leq 0.01$). Traps are represented by grey dots. Species are represented by black dots [for spiders: *Diplostyla concolor* (Diplcon), *Dysdera crocata* (Dyscro), *Erigone dentipalpis* (Eriden), *Microneta variaria* (Micvia), *Pardosa hortensis* (Parhor), *Tenuiphantes flavipes* (Tenfla), *Trachyzelotes pedestris* (Traped), *Troxochrus scabriculus* (Trosca), *Tenuiphantes flavipes* (Tenfla), *Zodarion italicum* (Zoda)]; for carabids: *Abax parallelepipedus* (Abapar), *Asaphidion curtum* (Asacur), *Calathus fuscipes* (Calruf), *Harpalus affinis* (Haraff), *Harpalus atratus* (Haratrat), *Nebria brevicollis* (Nebbre), *Notiophilus rufipes* (Notruf), *Pseudoophonus rufipes* (Pseruf), *Pterostichus madidus* (Ptemad)]; for staphylinids: *Aleo. spp*, *Anotylus inustus* (Anoinu), *Anthobium atrocephalum* (Antatrat), *Falagrioma thoracica* (Faltho), *Omalium rivulare* (Omariv), *Plataraea brunnea* (Platbru), *Sepedophilus testaceus* (Septes), *Stenus impressus* (Steimp)].

Table 2

Taxonomic and functional composition of spider, carabid and staphylinid communities in gardens using partial redundancy analysis (pRDA). Significance level (denoted. $p < 0.1$, * $p \leq 0.05$, ** $p \leq 0.001$, *** $p \leq 0.001$) are given for the entire model and for each term with an anova like permutation method ($n = 999$) (CG/DG, connection to the corridor; Dist = distance to the woodland, CMI = connectivity matrix index, Veg = vegetation cover under hedgerows).

	Spider		Carabids		Staphylinids	
	Taxonomic composition	Functional composition	Taxonomic composition	Functional composition	Taxonomic composition	Functional composition
Full model	1.23.	0.6	2.77**	2.78*	2.22**	3.75**
Details						
CG/DG	1.81*	0.21	5.79***	2.90*	3.02**	6.51**
Dist	0.71	0.18	2.15*	1.42	0.88	1.63
CMI	1.31	1.77	1.91*	5.92**	2.15**	6.22**
Veg	0.29	0.24	1.21	2.88	0.97	0.59

communities with high dispersal capabilities and low affinity to woodlands. For carabids, CG were at an intermediate position along this gradient whereas CG were functionally closer to corridor and sources for staphylinids.

For carabids and staphylinids, the garden analysis confirms that the connection to corridor (CG) and the CMI have positive effect for the habitat affinity and for species with low dispersal capabilities (respectively $p \leq 0.01$ and $p \leq 0.05$) (Fig. S2). We observed a significant effect of the distance to source (Dist) only for carabids.

4. Discussion

In this study, we assessed the effectiveness of green corridors, and in a less extent the connectivity of matrices, in enhancing biodiversity of urban domestic gardens. For the three taxa, we found close results on the taxonomic composition. Some differences were observed on functional compositions that could be explained by the dispersal capabilities of the species and by their various responses to landscape structures. Our results provide important information to be applied by land managers for sustainable planning of cities.

4.1. Positive effects of corridors

We highlighted that corridors strongly influenced the arthropod metacommunities of the surrounding gardens in urban landscapes and enhanced the dispersal of many species. Indeed, we observed that taxonomic and functional compositions of carabids, staphylinids and spiders communities of CG were closer to those of the corridors and the sources than the communities of DG. We observed

identical results for the three taxa that reveal strong underlying general processes in structuring community, such as dispersal limitation (Rosindell et al., 2011; Schweiger et al., 2005). Communities with low dispersal capabilities were associated with sources, corridors and CG, but less for spiders. Moreover, woodland affinity was associated with source, corridors and CG. Because woodland species function mostly in metapopulations (Petit and Burel, 1998), they are more sensitive to fragmentation and thus need corridors more than other species. By enhancing dispersal, corridors not only allow an increase of physical linkage between green spaces, but they also ecologically link green spaces and enhance the functional connectivity of urban landscapes.

For staphylinids, the effect of corridors was found even for species richness and abundance, both lower in DG compared with the other green spaces. Staphylinids are widespread taxa of arthropods that exhibit a great number of species and that seem to be sensitive to fragmentation (Deichsel, 2006; Michaels, 2007) and are particularly interesting for analysing the effects of urbanisation (Bohac, 1999; Deichsel, 2006; MacIvor and Lundholm, 2011). Without corridor connection, the community of staphylinids in DG was composed of few species with strong dispersal capabilities, allowing them to fly over many kilometres in cities (Tomlin et al., 1992). Moreover, source, corridor and CG were characterised by flightless species such as *P. brunnea*. As shown by the garden analysis, connection to corridor mostly explained these results. Contrary to many studies, the vegetation cover described here had a weak effect on arthropod metacommunities (Alaruikka et al., 2002; Le Viol et al., 2008; Niemelä et al., 2002; Small et al., 2003). The low variability of vegetation cover under hedgerows could explain this result. We regrouped many species in *Aleo. spp* representing 40% of

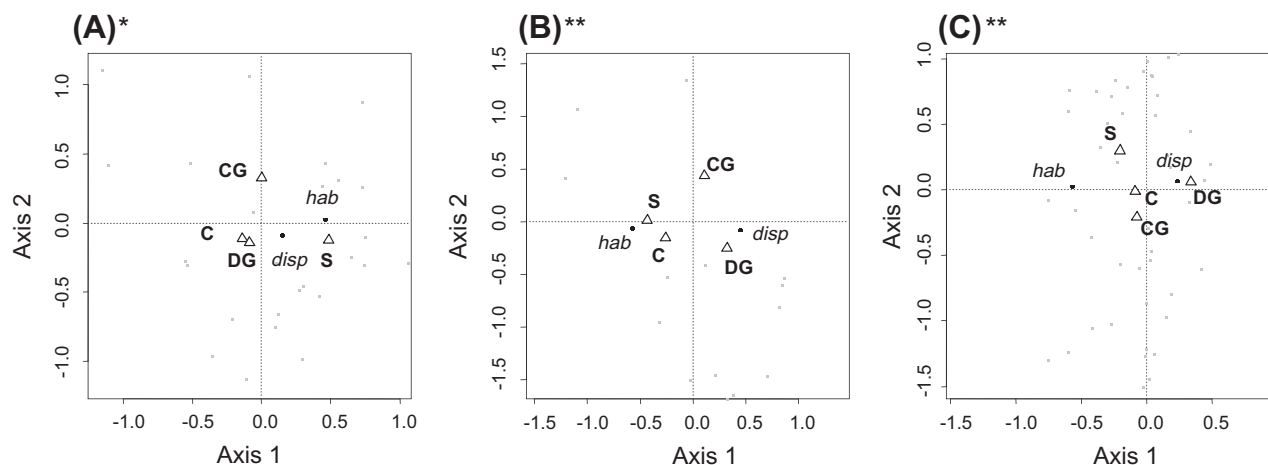


Fig. 3. Partial redundancy analysis (pRDA) biplot illustrating relationship between environmental and species attributes of spider (A), carabid (B) and staphylinid (C) metacommunities. For global analysis, we considered all types of green spaces (white triangle). We considered two species attributes (black dots): dispersal (disp) and affinity to woodland habitat (hab). p values are represented (denoted * $p < 0.05$, ** $p \leq 0.01$).

the total abundance, results on species richness of staphylinids should be tempered.

4.2. Heterogeneous response of taxa to landscape

Despite the similarity of some of the results, we observed several differences between taxa that could illustrate a heterogeneous response to landscape structure. The role of dispersal and local factors in community structure is an ongoing debate. Niche Assembly Theory considers that local factors and associate processes such as competition or facilitation mainly drive community composition (Gaston and Chown, 2005; MacArthur and Levins, 1967; Massol et al., 2011). In contrast, United Neutral dispersal assembly theory (UNT) highlights the central role of dispersal on shaping metacommunities (Hubbell, 2005; Rosindell et al., 2011). In our study, the sensitivity of metacommunities to isolation effects and, more generally, to landscape structure seems to depend on the dispersal capabilities of species (Goodwin and Fahrig, 2002; Holyoak et al., 2005). For carabids, mechanisms acting at wider scales (e.g., regional scale) and limiting dispersal could explain their rarity (McDonnell and Hahs, 2008; Whittaker et al., 2001). We did not find a lower species richness or abundance in DG for carabids, and they were extremely rare in gardens. In other studies conducted on urban domestic gardens, carabids represent an important part of abundance, for example 18% of all invertebrates, 60% of beetles and spiders in (Smith et al., 2006a). The rarity of carabids in gardens could be explained by a “source problem”. Indeed, carabids were rare even in sampled woodlots considered as sources for their local properties (e.g., vegetation and size) (a total of 25 species and 421 individuals and only 10 species and 50 individuals of woodland carabids were captured). The role of urbanisation should be investigated as is known to strongly affect the diversity of woodland carabids (Crocini et al., 2008; Gaubloome et al., 2008; Magura et al., 2010; Small et al., 2006). As the species richness and abundance of carabids were low in sources, they could not act as sources for propagules and could not be efficiently colonised corridors or, consequently, CG. Thus, the abundance of carabids in gardens was negatively affected by distance to source. Thus, CG close to the source supported more woodland carabids. More studies need to be conducted to clarify the effect of large scale mechanisms on carabids communities (McDonnell and Hahs, 2008; Whittaker et al., 2001).

Our results thus suggest both the importance of dispersal and niche processes in the structure of community (Gaston and Chown, 2005; Mouillot, 2007). We did not find a lower species richness in DG for spider metacommunities. Contrary to carabids, the species richness and abundance of captured spiders were comparable with others works conducted in urban landscapes (Alaruikka et al., 2002). Using ballooning, a majority of spiders can disperse from hundreds metres to hundreds of kilometres (Bell et al., 2005). However, Bonte et al. (2003) suggest that ballooning is negatively linked to the degree of specialisation, especially for woodland species. Thus, corridors may facilitate the dispersal of woodland species between source and connected gardens, but many generalist species coming from other sources could easily reach disconnected gardens, resulting in increased species richness.

Factors at the local scale, such as the composition of habitats, microclimatic conditions or patch area, could strongly shape spider metacommunities (Entling et al., 2007; Le Viol et al., 2008). Sources and gardens are quite different in local conditions. However, we did not find differences on local factors between CG and DG. Works on domestic gardens are still rare, and clear patterns of the effect of local factors have not been identified yet (Smith et al., 2006a). Interspecific competition has been suggested by some authors. For example, as a mechanism to explain spider community structure, interspecific competition could explain the exclusion of gen-

eralist species by woodland specialists (Connell, 1983; Wise, 2006) and, in turn, may explain the similar richness detected within CG and DG. For spiders, our results suggest the importance of both dispersal and niche processes in the structure of metacommunities (Gaston and Chown, 2005; Mouillot, 2007). Finally, despite a different taxonomic composition, communities in DG and CG shared a close functional composition. Further analyses focused on spiders and involving more traits were needed to analyse in what extent functional composition of spiders were not by landscape properties.

4.3. Importance of the urban matrix

We found that the connectivity of the matrix (CMI) surrounding gardens also shaped the taxonomic and functional composition of carabids and staphylinids. As showed by some authors, matrix properties could play a major role in the landscape connectivity and in corridor efficiency (Baum et al., 2004; Prevedello and Vieira, 2010; Rosenberg et al., 1997). In urban context, the matrix could strongly structure the communities and sometimes overpass species area relationship (Lizée et al., 2011). As showed by their effects on carabid species richness, some elements of the urban matrix as buildings or roads affected the dispersal of ground dwelling species but also of species flying at low altitude (Mader et al., 1990) whereas garden seem less impermeable to the dispersal of those species. Spider communities were not affected by the CMI. The majority of the species mainly present in gardens seem to have high dispersal capabilities and thus were not sensitive to the properties of the matrix.

4.4. Conclusions and application for landscape planning of cities

Our results suggest that both the role of corridors and in a less extent the urban matrix are crucial for enhancing biodiversity in urban green spaces such as domestic gardens. Using an indirect measure of spider, carabid and staphylinid dispersal (Jacobson and Peres-Neto, 2010), we show that, as in more natural landscapes, urban green corridors enhance dispersal and limit the effects of isolation by urban matrix. In cities, social and recreational values of corridors are well known (Savard et al., 2000). Ecological role of urban green corridors is supposed by many authors but was rarely clearly identified (Ahern, 2007). This study highlights their ecological role effects in maintaining ordinary biodiversity in highly fragmented landscapes and thus argues for the role of green corridors as an important part of green infrastructure for cities.

Using a multi taxa approach to analyse the effect of fragmentation, we underlined the major role of dispersal capabilities in landscape structure response and, thus, on metacommunity functioning (Hubbell, 1997; Leibold et al., 2004; McKinney, 2006; Rosindell et al., 2011). Processes acting at a wider scale, such as urbanisation, could be responsible for the rarity of some the weak dispersers, such as woodland carabids. Indeed, spiders and staphylinids, most of which have stronger dispersal capabilities than carabids, were abundant in the sources (Alaruikka et al., 2002; Deichsel, 2006). Our results highlight the importance of managing urban landscape at a wider scale and of reconnecting urban green spaces, including houses with domestic garden areas with more natural sources into regional green frameworks.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2011.11.002.

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