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Enhancing urban biodiversity and its influence on city-dwellers: An experiment

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ABSTRACT

Urbanization is presenting a growing problem for biodiversity conservation, notably by increasingly isolating over half of the world's population from the experience of nature. This separation of people from nature is an important environmental issue, as it could fundamentally influence the way people value nature and their willingness to conserve it. Here we provide the first experimental study that jointly explores how urban biodiversity can be enhanced and how these changes may influence some aspects of people–biodiversity interactions.

We significantly increased the diversity of flowers, birds and pollinators in small public gardens (Paris, France) by providing additional resources (i.e., planting flower-meadows and placing nesting-boxes). Semi-structured interviews were conducted *in situ* with 1116 regular garden users before and after the manipulation. Close-ended questionnaires were completed exploring the respondents' biodiversity perception and their sensitivity to the changes in biodiversity. Our results highlight a people–biodiversity paradox between people's perceptions and biodiversity awareness. Respondents expressed a strong preference for a rich diversity of species (excluding insects) and related this diversity to their well-being in the gardens. However, they did not notice the diversity of species. Respondents underestimated species richness and only noticed the changes in native flower richness in those gardens where advertisement and public involvement were organized. More experimental interdisciplinary studies are needed to further explore the people–biodiversity interactions. This would help expose the role that urban biodiversity plays in people's daily life and the importance of this interaction for raising public support for general conservation policies.

1. Introduction

Urban landscapes take up a mere 3% of the earth's land surface but accommodate more than half of the world's population (Wu, 2010). They pose a growing threat to biodiversity and contribute to physical, geographical and emotional separation of people from nature (Strohbach et al., 2009). Nevertheless, these expanding environments enclose networks of greenspaces and other environmental features, otherwise known as green infrastructure. This green infrastructure is typically strategically planned and designed to ensure the welfare of city-dwellers (Tzoulas et al., 2007). But it can also harbor a rich diversity of species and serve as unique grounds of cohabitation between people and nature (Miller and Hobbs, 2002). Green infrastructure is thus increasingly managed using 'biodiversity-friendly' practices with the aim of providing multi-functional services, and to improve the quality of life in cities (TEEB, 2011). Such measures are widely thought to contribute to making cities more sustainable, potentially reducing the detrimental impacts of urbanization (Standish et al., 2012) and improving people's well-being. However, it is not yet clear to what extent conserving urban biodiversity could achieve these goals and particularly, how daily experience of biodiversity could benefit people and increase conservation awareness (Fuller and Irvine, 2010).

Conserving urban biodiversity could generate multi-layered benefits for both city-dwellers and nature conservation (Dearborn and Kark, 2010). To date, much of urban conservation research has focused on the ecological aspect, by exploring the variables that influence species diversity in cities (Sadler et al., 2010). These studies have demonstrated that some structural features (e.g., tree cover, diversity of habitats) and management practices can provide

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better conditions for urban biodiversity (e.g., Gaston et al., 2005; Fuller et al., 2008; Fontana et al., 2011). Yet, to our knowledge, most of those studies remain observational. Experimental approaches, such as modifying environmental features and exploring the impacts of these features on urban biodiversity, remain scarce (but see Gaston et al., 2005; Matteson and Langellotto, 2010). Furthermore, studies that explore the role urban biodiversity plays in providing cultural services, and in reconnecting people to nature, remain scarce. The handful of studies that tackled this issue showed that this relationship (i.e., people–biodiversity) is more complex than commonly argued (Dallimer et al., 2012; Shwartz et al., 2012; Standish et al., 2012).

Establishing the role that species diversity plays in the daily life of city dwellers involves understanding people's perception of biodiversity, as well as the conscious and subconscious benefits they gain from exposure to biodiversity. Lindemann-Matthies and collaborators (2007, 2010) have demonstrated that people prefer flower meadows that exhibit a higher diversity and that people also provided reliable estimations of flower richness. Positive correlations between perceived and sampled richness was only found for plants in urban greenspaces in the city of Sheffield (UK), but not for birds and butterflies in the same greenspace and for the three taxa in riparian habitats (Fuller et al., 2007; Dallimer et al., 2012). The latter study also showed that people had poor biodiversity identification skills. These results suggest that people are not consciously aware of most components of biodiversity, apart from plants. An intriguing possibility is therefore that provision of information, beyond sheer exposure to biodiversity, could help increase people's awareness about biodiversity and reconnect them to nature (Shwartz et al., 2012). In fact, it is well established in the psychological literature that providing information could influence people's attitudes (Allum et al., 2008). For instance, when information regarding birds was added to questionnaires, people exhibited a greater preference for natural greenspaces and were willing to pay more for their creation (Caula et al., 2009).

Evidence demonstrating improvement of personal well-being from exposure to urban nature or 'green' has been accumulating (reviewed by Tzoulas et al., 2007; Matsuoka and Kaplan, 2008), but only a few empirical studies have attempted to relate these benefits to biodiversity. Fuller et al. (2007) found that several measures of well-being were positively correlated to species richness of plants and to a lesser extent of birds, but not of butterflies. Dallimer et al. (2012) found no consistent relationship in riparian habitats and Luck et al. (2011) found that demographic factors were much more important than environmental factors in influencing the well-being of respondents. However, their study was limited to low to medium density neighbourhoods, and they hypothesized that in large metropolises psychological benefits would be more important, which has not been explored to our knowledge.

Thus, there could be a potential discrepancy between the ecological (conserving biodiversity) and social (connection to nature and dwellers' well-being) objectives in urban conservation (Standish et al., 2012). Since humans are the keystone species in the urban ecosystem, effective conservation should seek 'win-win' solutions for the mutual benefit of conservation and people. Nevertheless, since land is a highly prized commodity in urban areas, the scope for changes in biodiversity is often limited and competes with other interests people may have from green infrastructure (Shwartz et al., 2013a). The overall objective of this study was to provide a first experimental test exploring whether increasing species diversity in public gardens could enhance the connection of people with nature. Specifically, we aimed to investigate: (1) whether a set of common 'biodiversity-friendly' practices could effectively increase species diversity? (2) Whether these changes had an effect on garden visitors' awareness and perception of species diversity? This could provide some insights on the potential of these actions in connecting people with nature, which serve as important motivation for conserving urban biodiversity (Dearborn and Kark, 2010); (3) To what extent providing information and involving garden visitors in the process of increasing biodiversity could enhance awareness and perception of biodiversity?

2. Methods

2.1. Experimental design

The research was conducted in small public gardens (hereafter referred to as gardens) in Paris (France), one of the largest metropolises in Europe. Since private gardens are scarce in Paris, these gardens serve as the primary grounds where people can interact with biodiversity (Shwartz et al., 2013b). We selected 14 small recreational gardens with similar size ($\sim$1 ha), classified in three groups of 4–6 gardens, each group representing a different socio-economic context (low, medium or high). Within each group, gardens were similar biologically (diversity and environmental variables) and socio-economically (further information on garden selection could be found in Supporting information). The gardens within a group were spatially independent from each other (tested in Shwartz et al., 2013a), typically separated by large buildings and a minimum distance of 300 m.

Two sets of related experiments were conducted. In the first experiment, we tested whether biodiversity-friendly practices led to a measurable increase in species diversity. In the second we tested whether garden visitors noticed these changes in species diversity by using a visitor surveys. The experimental design (Fig. 1) was setup as follows: we used a block design, such that within each group, we selected two manipulation gardens (MAN) in which we used a range of methods to increase species diversity, and two control gardens (CON). In one of the manipulation gardens the increase in species diversity was performed with the involvement of garden visitors (MWI, Fig. 1), and in the other without (MWoI, Fig. 1). In one of the control gardens, only biodiversity was surveyed (CON E, Fig. 1) and in the other both biodiversity and garden visitors were surveyed (CON E+S Fig. 1). Thus, changes in biodiversity were compared before and after the manipulation and between the two pairs of gardens (MAN and CON gardens). Similarly, the perceptions of garden visitors were compared before and after, and between MWI, MWoI and CON E+S gardens.

Our target was to sample 75 regular visitors per gardens before and after the manipulation (altogether 150). However, due to feasibility reasons we had to reduce the sample size. We decided to sample fewer visitors in the control gardens ($n = 100$ altogether), since we were mostly interested in tracking differences in perception following the manipulation. Social control gardens were only serving to account for potential independent changes in visitors' perception through time, which could have confounded the interpretations of our results. The target sample size was achieved in all manipulation gardens except one, due to poor visitation frequencies (Table A1). Since this problem was anticipated, we conducted the manipulation without involvement in an additional garden (to ensure a sufficient sample size of questionnaires), with an additional control. This explains why a total of 14 gardens were sampled.

2.2. Increasing species diversity

Throughout the research (2009–2010) the gardeners (i.e. the employees of the Paris municipality who are responsible for maintaining the gardens) were asked to employ similar practices in both CON and MAN gardens (e.g., planting the same composition of flowers in seasonal flowerbeds). In the MAN gardens we employed

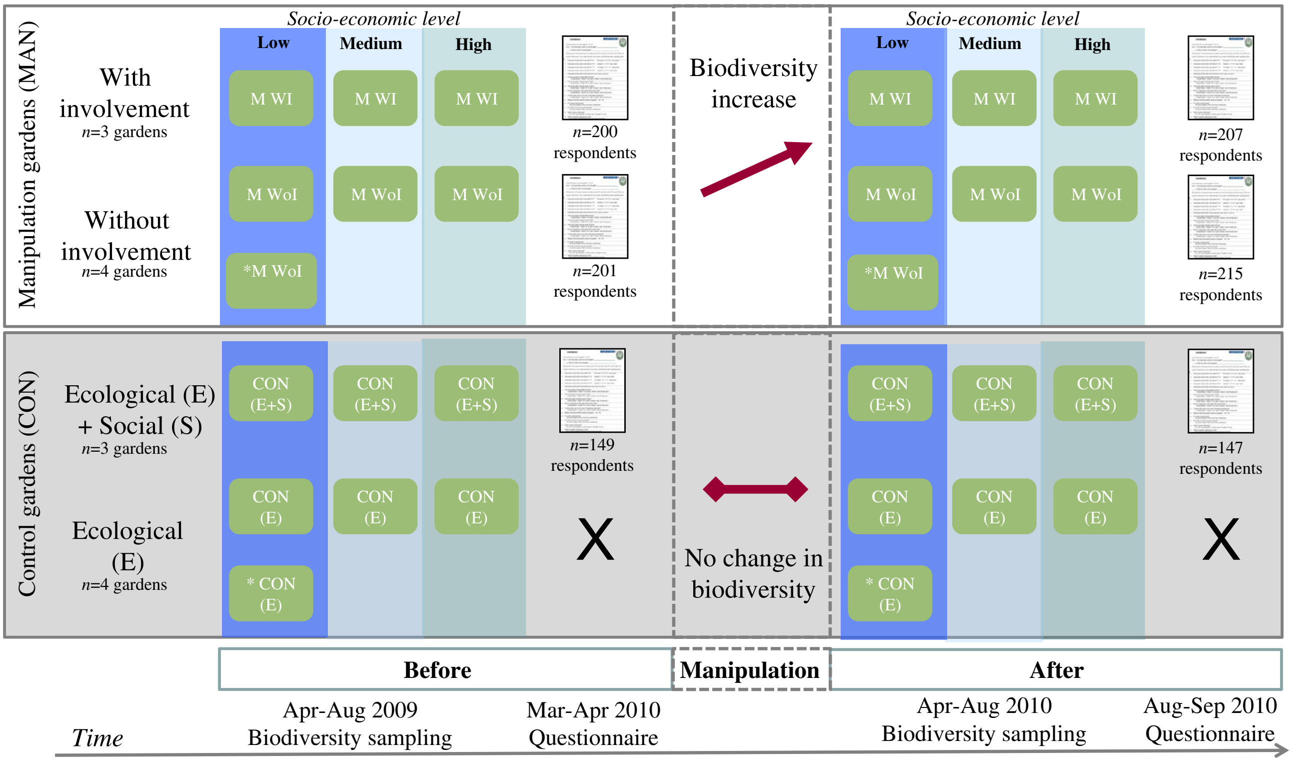

Fig. 1. A scheme presenting the experimental design used in this study comparing differences in biodiversity and biodiversity perception before and after the manipulation and between manipulation gardens with involvement (MWI), manipulation gardens without involvement (MWoI) and control gardens (CON E and CON E+S). The asterisk marked the MWoI garden that was added due to poor visiting frequencies, and its matching CON E garden.

a range of methods to increase the diversity of flowers, birds and pollinators with the collaboration of the gardeners. In each garden, the diversity of flowers was increased by converting a patch of lawn of 30 m^2 into a flower meadow. A mix of thirteen flower species was sowed between the end of April and the beginning of May 2010, to attain peak flowering in June-July (Fig. A2; for species lists see Table A2). The flower composition included flowers that provide nectar for pollinators and species that can serve as host plants for butterflies (Table A2). A patch of starflower (*Borago officinalis*; Fig. A2), known to attract several pollinator species (Royan and Roth, 1998), was also planted in each garden. Additionally, in 2010, we asked the gardeners to avoid weeding plants that can serve as hosts for butterflies, such as nettles (*Urticaceae*) and plants from the bean family (*Fabaceae*). Finally, for both pollinators and birds, we placed nine nest-boxes in each garden (Fig. A2; see Table A3 for specific dimensions and details about the nest-boxes and target species).

2.3. Biodiversity survey

Species diversity was sampled in the same manner in the seven MAN gardens and in the seven CON gardens before (2009) and after (2010) the manipulation. Since gardens were small (~1 ha), each garden served as a sampling unit (i.e., one sampling point/transect per garden). The distribution of visits before and after the manipulation was planned in advance to ensure that each garden was sampled at different times of day and at regular intervals throughout the survey period. All sampling was conducted by the same two observers to avoid observer bias. We selected the three different taxonomic groups that were both relatively well-known to people and for which we believed that we could increase the species diversity relatively easily.

Birds were sampled during the breeding season (April–May) between 30 min before sunrise and three hours after sunrise using point counts. We visited each garden 16 times (8 before and 8 after) and recorded every bird seen or heard up to 50 m from the sampling point for 10 min. Birds flying over the survey area (over treetops) were ignored. For each entry we recorded the species, the number of individuals, as well as distance from the observer. We used two different methods to sample pollinating insects. Butterflies (*Lepidoptera* sp.) were sampled from June to August on sunny days with temperature above 18 °C. We used the quadrat method as it was more suitable than normal transect sampling for the gardens that were relatively individual- and species-poor. Thus, for each garden we defined a quadrat of 0.5 ha in which we directionally strolled (never returning back) for 15 min recording any butterfly in sight. When needed, in order to verify identification, we captured and immediately released butterflies with a sweeping net. All butterflies were identified at the species level except small whites, which were grouped at the genus level (i.e., *Pieris*). Each garden was visited 14 times (7 before and 7 after the manipulation).

In order to get an idea of the diversity of the other numerous pollinators and to create a comparable index between gardens without capturing individuals, we used a digital camera to sample pollinators in the peak flowering season (June–August). Each garden was visited 14 times (7 before and 7 after the manipulation) for 20 min on sunny days between 9:30 and 17:30. We sampled pollinators by photographing the insects, which were located on flowers (for further details see Shwartz et al., 2013b). Later, from photographs we identified pollinators to morphospecies level (i.e., a group of species distinguished from others only by its morphology).

The diversity of flowers was not sampled systematically since we artificially increased flower richness. However, to control for those changes we conducted two counts of both ornamental and wild flowers at the end of July 2009 and 2010. This was done by taking pictures of all flowering species with small digital camera and later identifying them in the lab. To validate this method in the first sampling season July–August 2009 each garden was visited by a skilled botanist, who recorded all flowering species (see Shwartz et al., 2013b). We compared the two lists and found no differences in the number of flowering species.

Sampling effort was estimated for birds, butterflies and other pollinators in each garden using sample-based rarefaction curves (Colwell et al., 2004). We used the observed richness when all gardens reached accumulation (birds and butterflies) and the average number of species if not (other pollinators, for further details see Supporting information).

2.4. Informing and involving garden visitors

In MWI gardens, we employed several methods to increase the awareness of garden visitors towards the diversity of species found in their local public gardens. First, we organized three activity-days in April 2010 (one in each MWI garden), gathering over 250 participants altogether (Shwartz et al., 2012). In those activity days, we presented the local biodiversity, the methods used to increase this diversity (Table A3) and offered visitors the opportunity to participate in conservation activities. In addition, passive information on species diversity was provided for all visitors by placing signs around the nest-boxes and the flower meadow. In MWI gardens, gardeners and guards were also asked to share biodiversity information as much as possible with the public, while in MWoI gardens they were asked to avoid providing any information on the project.

2.5. Garden visitors surveys

We conducted a survey to explore whether and how an increase in biodiversity influenced our research population, frequent visitors of small public gardens. We only interviewed frequent visitors, since we did not expect that people who rarely used the gardens could experience the changes in biodiversity. This could have resulted in a self-selection bias for respondents who are likely to already have a more positive attitude to the gardens. We developed our own questionnaire based on theory and research within social-geography (Kaufmann, 2011) and environmental psychology (Fuller et al., 2007 and references within). We followed previous surveys exploring people's perception of biodiversity in the metropolis of Paris (e.g., Simon and Goeldner-Gianella, 2012). The questionnaire consisted of 33 questions, but only 19 were used in the scope of this study (for the full questionnaire see Supporting Information). It was reviewed by colleagues and students in our department prior to a formal pilot with garden visitors. We did not use other validity measures, such as focus group discussions, that could have been helped developing the questionnaire in a more rigorous fashion. For piloting the questionnaire, we conducted ten in-depth interviews with garden visitors, exploring wording and internal validity of the questions. We revised the questions where needed. For instance, the word 'pollinators' and 'species' were replaced by 'insects' and 'types' since interviews showed that not all respondents understood their meaning.

Our survey addressed two main topics: biodiversity perception and sensitivity to biodiversity. Biodiversity perception was measured via items related to interest in biodiversity and visitors' perception regarding the influence of biodiversity on their well-being in the garden. Interest in biodiversity was estimated through four items aiming to identify how many species visitors would like to see in the gardens. These items were asked in a similar way for birds, flowers, insects and trees, and respondents were asked to give an answer on a scale from 0 to 5 (zero: no species, five: many species). We developed an additional set of items to explore biodiversity well-being perception following Simon and Goeldner-Gianella (2012). This included six items exploring to what extent visitors perceived richness of flowers, birds (species and songs), insects and trees to influence their well-being in the gardens. Responses were made on a five-point Likert scale from strongly disagree to strongly agree, based on the stem question 'Please indicate how much you agree with each of the statements below'. We then constructed a *biodiversity perception* measure summing those items, after confirming the measure's reliability, by verifying that Cronbach's alpha was superior 0.7 (0.77) and that inter-item correlation was not inferior to 0.3 or superior to 0.7 (Rattray and Martyn, 2007 and ref. within).

Sensitivity to biodiversity was estimated through three semi-open questions (for flowers, birds and insects) to explore whether visitors had the impression that there were different species in the garden (yes/no). When respondents answered yes, they were asked to give a rough estimation of the number of species and only those respondents were used in the analyses pertaining to the *sensitivity to biodiversity*. These data were used to calculate three estimated richness variables (one for each taxa). Finally, we asked several questions to learn more about the socioeconomic profile of respondents (*gender*, *age*, *income*, *qualification* and *childhood environment* [in which context, urban vs. rural, respondents spent most of their childhood]). We also asked respondents for what purpose they visit the gardens. Further description of those variables, as well as the distribution of the answers, are available as Supporting Information (Table A4).

2.6. Data analysis

Wilcoxon's sign-rank tests were used to compare the richness and abundance of birds, butterflies and other pollinators between 2009 and 2010 between experimental and control gardens. Since 2009 was an exceptional year in the abundance of the migratory butterfly painted lady (V*anessa cardui*) across Europe (Fox, 2010) and it was frequently seen flying across the gardens, we also compared the abundance of more residential butterflies only before and after the manipulation.

We used four generalized linear mixed models with Poisson and negative binomial (accounting for over-dispersion) error structure to explore differences in *biodiversity perception* and in *sensitivity to biodiversity* of birds, flowers and insects before and after the experimental manipulation. We tested for the effect of biodiversity increase (two-level factor: before vs. after; *context*) and involvement (three-way factor: control, with, and without involvement; *treatment*) on the estimated number of species, by testing for the interaction context * treatment. In addition, we also controlled for six independent socio-demographic variables and for pseudo-replication across gardens by including garden identity as a random term. We checked for the absence of collinearity between the independent variables and tested the model's assumptions using residual and leverage plots. For model selection, we used the model-averaging approach (Burnham and Anderson, 2002). We ranked all models on the basis of the AIC_c (corrected Akaike information criterion). For variables from the most parsimonious models (i.e., $\Delta AIC_c < 10$), we averaged their estimates and standard errors weighted by each model's AIC_c (Burnham and Anderson, 2002). Model averaging yielded the post-probability (hereafter PP) of an explanatory variable affecting the dependant variable and took into account the number of times the term appeared as significant in the selected models.

Finally, we also checked whether there was a correlation between the average estimated species richness of birds, flowers and pollinators in each garden and the observed richness using Spearman's rank test. Thus, correlations were tested separately for each taxa. Although we did not use the word 'pollinators' in our questionnaire, we compared number of insects to the richness of pollinating insects, which is under-representative of the whole insect richness. All the statistical analyses were done in R.2.12.2 (R Development Core Team 2011).

3. Results

The range of methods we employed to increase species diversity proved useful, as significant increases in species richness and abundance were recorded in MAN compared to CON gardens (Fig. 2). We added 14 species of flowering plants to all MAN gardens and more than tripled the abundance of residential butterflies after the manipulation, from 1.98 individuals on average to 6.46 (Wilcoxon $Z = 2.37$, $p = 0.018$; Fig. 2). When migrating butterfly species were considered however, no difference in richness and abundance were observed before and after. More notably, after the manipulation, the overall richness of other pollinating rose from 18.42 to 27.43 (i.e. a 49% increase), and the number of species sampled per visit was significantly higher (Wilcoxon $Z = 2.37$, $p = 0.018$; Fig. 2). Similarly, the richness of birds was significantly higher after placing the nest-boxes than before (additional 3.2 new species per garden on average representing a 26% increase; Wilcoxon $Z = 2.21$, $p = 0.027$; Fig. 2) and the abundance of the seven targeted cavity nester species more than doubled in MAN gardens (2.25 new individuals on average; Wilcoxon $Z = 2.37$, $p = 0.018$). During sampling, nine nesting attempts of those target species (in six gardens) were observed, including tits, robin, black redstart and treecreeper. No significant differences were recorded in the abundance of all birds.

However, we found no significant differences in the *perception of biodiversity* of garden visitors before and after the experimental manipulation, or between MWI, MWoI and CON E+S gardens (Table 1). Altogether, we interviewed 1116 garden visitors that lived near the gardens and visited them frequently (3.15 visits per week on average; Table S1). Most visitors came to the gardens for children recreation (43%) or for relaxation (28%). Although only 9% of respondents mentioned that they were visiting the gardens to interact with nature, most of them expressed the wish to see many species and related those species to their well-being in the gardens. The modes for most answers to *biodiversity perception* items (except insects ones) were either four or five (i.e., the higher values). However, perceptions differed according to the taxonomic group. While most respondents wanted to have many species (i.e., answers 4–5) of flowers (89%), trees (83%) and birds (57%), only 23% wanted to have insect-rich gardens (Table S2). Similarly, while most respondents agreed or strongly agreed with the statements that flower diversity (95%), bird diversity (84%), different bird songs (58%) and tree diversity (61%) improved their feeling of well-being in the gardens, only 37% felt the same way regarding insects (Table S2). It also seemed that older, more educated respondents, men and respondents who had spent most of their childhood in greener environments scored higher in the *biodiversity perception* measure (Table 1).

Overall, garden visitors were not very conscious of the diversity of species neither in the gardens nor to the changes that we introduced. Garden visitors exhibited relatively poor ecological skills and we did not find any significant correlation between observed and estimated richness. We found that most participants underestimated the number of species present in the gardens. For flowers, 92% of the respondents underestimated flowers richness by 50% or more. Among them, 229 respondents thought that there was no more than one type of flower in the garden. Similarly, for both insects and birds, 93% of the respondents underestimated richness by over 50%. Among these respondents, 438 and 259 visitors respectively, thought that the gardens had no more than one insect or bird species. Moreover, garden visitors only partly noticed the experimental increase in species diversity. After the manipulation, visitors to MWI gardens estimated a significantly higher number of flower species than visitors to MWoI gardens or visitors to control gardens (Table 1; Fig. 3). A similar trend towards higher estimates

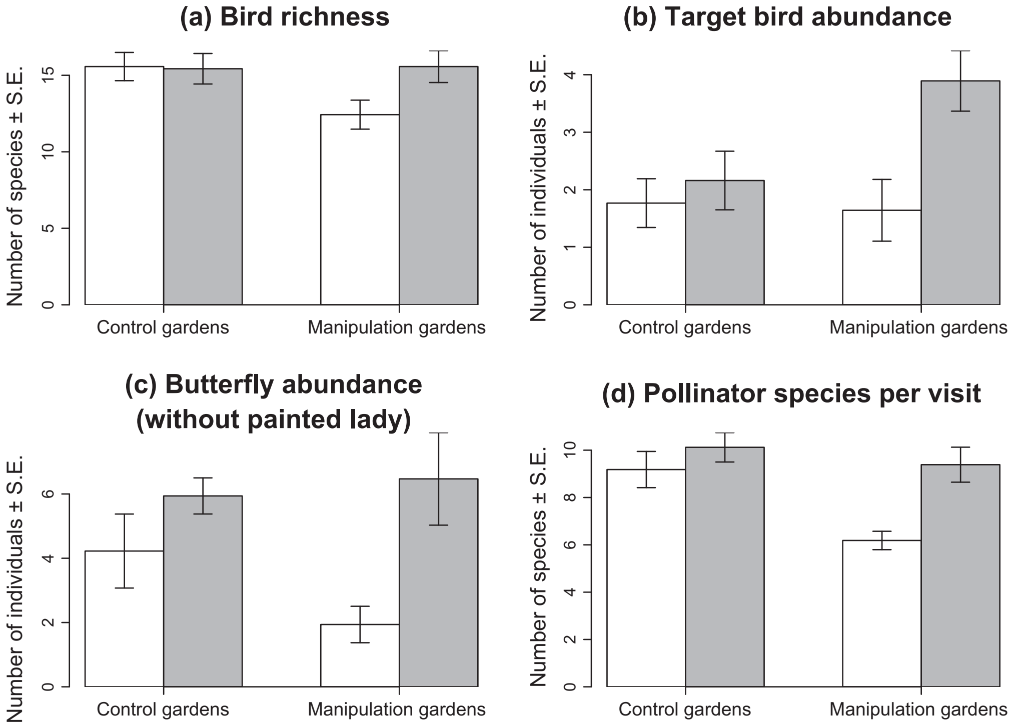

Fig. 2. Bar charts showing the effect of the experimental manipulation on biodiversity. Average ± SE of (a) bird richness, (b) target bird abundance (i.e., the abundance of species that could use the nest-boxes), (c) butterfly abundance (excluding the painted lady), and (d) number of pollinator species per visit, before and after the manipulation for both control (CON gardens) and manipulation gardens (MAN gardens).

Table 1

The results of the four generalized linear mixed models exploring people's biodiversity perception ($n = 967$), estimations of flower ($n = 743$), bird ($n = 730$) and insect ($n = 521$) richness before and after the manipulation and among treatments (with and without participation and control), while controlling for six profile variables. Estimated average coefficients ± S.E. are presented for important variables (i.e., post-probabilities > 0.5).

Variables	Biodiversity perception Coefficient ± SE	Estimated bird richness[a] Coefficient ± SE	Estimated flower richness[a] Coefficient ± SE	Estimated insect richness[a] Coefficient ± SE
Intersect	6.219 ± 1.710**	1.121 ± 0.123**	1.465 ± 0.179**	2.417 ± 0.236**
Gender (male)	0.024 ± 0.010*	0.150 ± 0.050**	0.147 ± 0.061*	0.362 ± 0.096**
Age	0.002 ± 0.000*	0.005 ± 0.002**	0.011 ± 0.002**	−0.016 ± 0.003**
Qualifications	0.020 ± 0.002**		0.032 ± 0.016*	0.086 ± 0.024**
Childhood environment	−0.016 ± 0.004**			−0.077 ± 0.390*
Visit frequency		0.004 ± 0.001*	0.005 ± 0.002*	0.005 ± 0.003*
Context (after)			0.378 ± 0.108**	0.318 ± 0.114**
Treatment (MWI)				
Treatment (MWoI)		−0.086 ± 0.062*	0.055 ± 0.097**	
Treatment (CON)		−0.115 ± 0.071*	0.089 ± 0.114**	
Treatment (MWI)* Context (after)				
Treatment (MWoI)* Context (after)			−0.268 ± 0.135*	
Treatment (CON)* Context (after)			−0.524 ± 0.157*	

*,** flag significance levels <0.05 and <0.01 respectively, based on a rule of thumb for using post-probabilities that PP > 0.95, 0.95–0.5, and <0.5 corresponded roughly to p-values < 0.01, 0.01–0.05, >0.05 (following Shwartz et al., 2013b).

[a] Negative binomial error structure was used to account for over-dispersion.

after the manipulation, regardless of treatment, was also found for birds (marginally important $PP = 0.49$) and for insects (Table 1). The latter was strongly driven by changes in control gardens (Fig. 3). Men and older respondents tended to give higher and more realistic estimations (Table 1). Similarly, flower and insect estimations were positively associated with qualification level (Table 1) and respondents that grew-up in greener environments gave higher estimations of insect richness. Finally, respondents who visited the garden more frequently provided higher (more realistic) estimations of all three taxa (Table 1).

4. Discussion

Planning sustainable cities that meet the needs of people today without compromising the ability of future generations to meet their own, may well be the grandest challenge to humans ahead (Wu, 2010). Achieving this challenge requires developing innovative urban planning and management solutions that value biodiversity, but also strong public support to encourage decision makers to implement those policies (TEEB, 2011). It is therefore important to understand the effectiveness of such solutions in enhancing urban biodiversity, but also the consequences of such changes on the perception of city-dwellers about conservation. The results of the two experiments demonstrated a high success in increasing species diversity on the one hand, but a rather limited effect of those changes on the perception of garden visitors on the other hand. However, they also showed that efforts to involve visitors in conservation action could increase their awareness to some components of biodiversity. To our knowledge this study is the first to go beyond observation and experimentally increase species diversity in order to explore the influence this has on citizens.

Our first experiment showed a substantial increase in the diversity of plants, birds and pollinators. Positioning nest-boxes in urban areas could be useful in maintaining populations of cavity nesting birds (Jokimäki, 1999; Davies et al., 2009), since cities are characterized by a low availability of nesting sites (Newton, 1994). Indeed, we found that bird richness and abundance of target species increased significantly after the manipulation, while no differences were recorded in control gardens. For pollinators, while other studies found that sowing flower meadows (Matteson and Langellotto, 2011), introducing nest-boxes or allowing nettle growing (Gaston et al., 2005) were moderately successful, we found that combining these methods could be effective in enhancing diversity. Thus, supplementing both feeding and nesting resources can have a rapid short-term positive influence on biodiversity in small public urban gardens. Nevertheless, we find it important to highlight that the conservation effectiveness of enhancing urban biodiversity by using such practices remains unclear (Shwartz, 2012), and therefore should not serve as a justification for other destructive planning.

The main findings from the second experiment revealed that this enhancement of species diversity had a limited influence on the *biodiversity perception* of frequent visitors of Parisian gardens. We did not find any differences in *biodiversity perception* before and after the manipulation, and between MWI, MWoI and control gardens. The biodiversity perception measure comprised of two sets of items: interest in biodiversity and the influence of biodiversity on the well-being of visitors in the garden. Benefiting from biodiversity does not necessarily require people to be aware of species around them. For instance, green infrastructures can improve people's well-being by regulating temperature or reducing pollution (TEEB, 2011) regardless of the awareness of people to those processes. However, it can be argued that if garden visitors were consciously aware of changes in species diversity and appreciated them, they would be more likely to support conservation efforts. We would thus find a linear relationship between those two sets of items and species diversity in the gardens. This was not found. Moreover, we found that garden visitors had contrasting interests for different aspects of biodiversity, as they expressed a high preference for flower diversity compared to birds and trees, and avoided insects. Together, these results show that the relationship between biodiversity and city-dwellers is not as straightforward as commonly argued (Dearborn and Kark, 2010), unveiling a people–biodiversity paradox (Fuller and Irvine, 2010). On the one hand, visitors expressed general appreciation for species diversity and related it to their well-being in the garden. On the other hand, visitors neither noticed this diversity nor the changes we implemented. Thus, enhancing biodiversity may not necessarily promote a positive connection that will increase conservation awareness. Below we discuss several hypotheses, alternative explanations and limitations of our study that could shed light on this complexity and direct future research and urban conservation action.

Lack of interest in nature, or limited capabilities to experience nature's fine complexity, could explain the lack of change in biodiversity perception among frequent visitors to Parisian gardens. Our results suggest that the former was not the case in our study. Interviewees expressed appreciation for species diversities (excluding insects) and related it to their well-being in the garden. This could stem from a response bias (Paulhus, 1991) due to the positive nature of our items, or a self-selection bias for people with positive

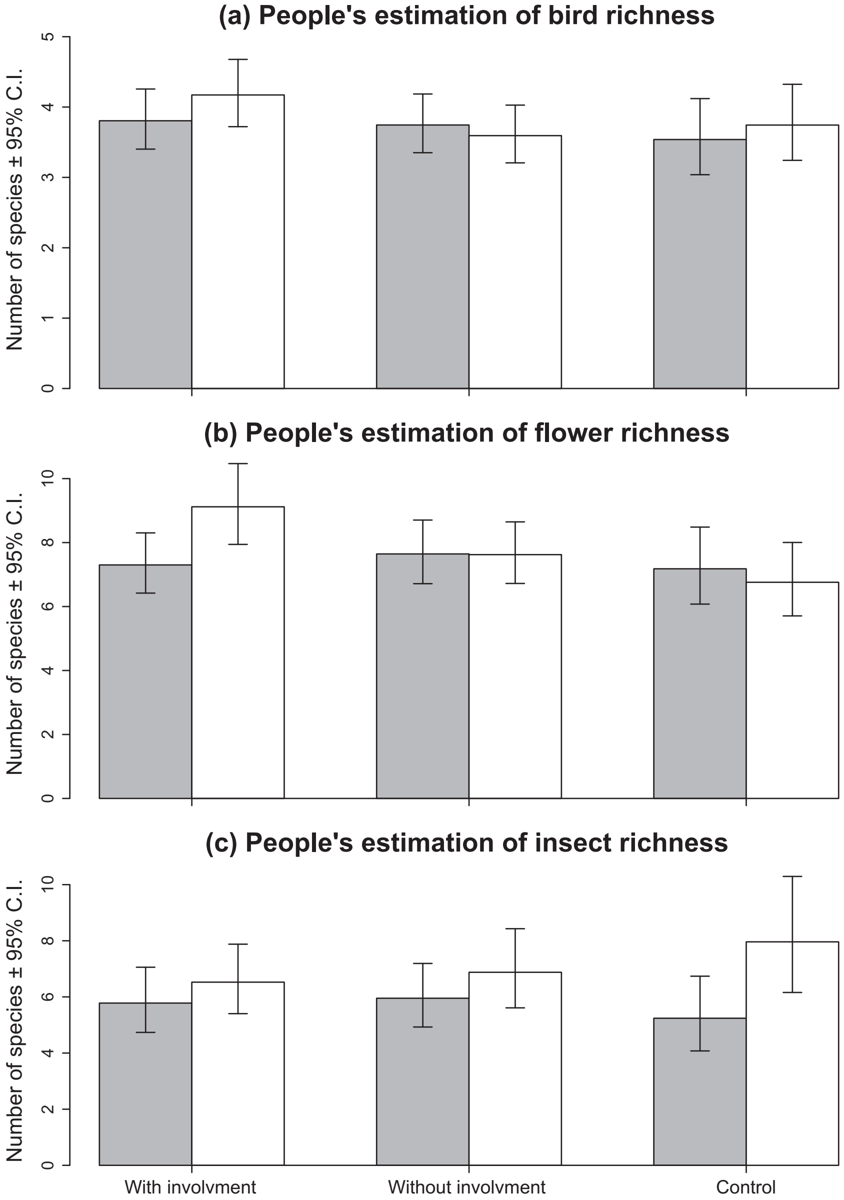

Fig. 3. Bar charts showing comparing garden visitors' estimations of species diversity before and after the experimental increase in biodiversity. Average ± CI of people's estimations of bird (a), flower (b) and insect (c) richness before (gray) and after (white) the manipulation for the three treatments: manipulation with involvement (MWI), without involvement (MWoI) and control (CON E+S).

attitude to the gardens. Developing negative oriented items and other less biased methods to explore biodiversity perceptions (e.g., Shwartz et al., 2013a), but also monitoring the rejection level (i.e., refusal to be interviewed) could help in understanding and dealing with those potential biases. However, several other studies in urban Europe have already demonstrated greenspace visitors' appreciation for biodiversity (e.g., Clergeau et al., 2001; Lindemann-Matthies et al., 2010). On the other hand, regular visitors to the gardens strongly underestimated species richness across all taxa and these estimations were not correlated with the observed species richness. Another study has also demonstrated that city-dwellers generally have poor ecological skills (Dallimer et al., 2012), especially in the case of birds and pollinating insects (see as well Fuller et al., 2007). Regular garden visitors were also not able to notice the changes in biodiversity that we implemented. Only changes in flower richness were noticed in the MWI gardens, in line with other studies that showed that visitors appeared better able to estimate plant biodiversity than the biodiversity of other taxa (Fuller et al., 2007; Lindemann-Matthies et al., 2010).

Alternatively, garden visitors may not have noticed the changes in biodiversity because, although significant, these changes were spread over a long period of time (across two successive years) and were relatively small, involving a few species and only small structural changes. We cannot completely rule out this explanation and future research should aim to explore the consequences of far-reaching changes (e.g., conversions of built areas to greenspaces) on people's life. However, our experimental design was such that visitors were exposed to richer diversities after the biodiversity manipulation (late summer) than before (late winter), simply due to the natural life cycle. We could thus have expected changes in biodiversity perception even in control gardens, but this was not observed. The lack of correlations between observed and perceived richness strongly suggests that garden visitors do not notice key elements of biodiversity, regardless of the size of change. Moreover, the level of changes we achieved appears analogous to what can be achieved in similar urban environments (e.g., Day, 1995; Shwartz et al., 2013b), considering that cities have space constraints for urban nature (Standish et al., 2012). Efforts to increase people's conservation awareness in cities may thus be in vain unless we gain a better understanding of those aspects that people may notice.

Conservation education activities could help with reconnecting people to biodiversity (Shwartz et al., 2012), especially when changes are more difficult to notice. Indeed, we found that estimations of flower richness in MWI gardens were significantly higher after the manipulation, while bird and insect richness demonstrated a similar but non-significant trend (Fig. 3). These results concur with other studies, which found significant positive correlations between greenspace visitors' estimations and species richness of plants, but not of other taxa (Fuller et al., 2007; Lindemann-Matthies et al., 2010). Therefore, it seems that increasing the structural complexity of the greenspace could be more effective at raising people's awareness for biodiversity than increasing the biodiversity of other taxonomic groups that require a higher level of species identification skills. Well-designed conservation education activities may also raise people's biodiversity awareness. In this study, our results are in fact limited to the effects of provisioning passive information, since among the 569 garden visitors that we interviewed after the manipulation, only nine participated in our activity days. Passive information, through signposting in zoos for instance, can significantly increase people's awareness to local biodiversity (Mayer and Slotta-Bachmayr, 2005). Accordingly, in a related study, we demonstrated that participants to the activity day were mostly unaware of their local biodiversity, but partaking in the activities raised a long lasting interest for the biodiversity found inside the gardens (Shwartz et al., 2012). In practice, interaction with nature is not the first reason for visiting public gardens (see as well, Irvine et al., 2013; Shwartz et al., 2013a). Therefore, planners may need to consider all competing interests to decide how to implement solutions that facilitate people–biodiversity interactions.

The extinction of experience hypothesis could also explain the weak and complex relationship found here and in other studies between people and biodiversity (e.g., Fuller et al., 2007; Luck et al., 2011; Dallimer et al., 2012). This hypothesis argues that urbanization, and other processes, increasingly isolates the human population from the experience of nature (Pyle, 1978), which could cause a reduction in people's capabilities to experience biodiversity. Accordingly, respondents who interacted longer with nature in their lifetime tended to demonstrate higher levels of biodiversity knowledge and conservation concern (Tanner, 1980; Lindemann-Matthies and Bose, 2007, 2008). These included people who grew up close to nature during their childhood, older respondents who grew up in a less urbanized world or who were simply exposed for longer to nature than younger ones. We found that this category of respondents also scored higher in *biodiversity perception* measures and provided higher (more realistic) estimations of species richness. These results provide only tenuous evidence to support the extinction of experience hypothesis. A landscape approach would be required to establish it. This could imply exploring people's experience of biodiversity in different levels of urbanization and relating this experience to their ecological skills and conservation perception. It is important to further explore this hypothesis, since if the extinction of experience modifies the way people value/notice the complexity of nature, then raising public support for biodiversity conservation may become more complicated (Fuller and Irvine, 2010).

However, looking for consciously identifiable effects of biodiversity may miss subconscious effects at play. Indeed, only 9% of interviewees indicated that nature was one of their main reasons for visiting the gardens. Similar patterns (15%) were recorded among visitors of larger greenspaces in Sheffield, UK (Irvine et al., 2013). This indicates that visitors are not consciously seeking nature when visiting the gardens and this could explain why we did not find differences in *sensitivity to biodiversity* and *biodiversity perceptions* before and after the manipulation. An extensive body of literature in environmental psychology has explored the subconscious impacts of experiencing nature. Although the causal mechanisms of nature's impact are not yet clear, two main theories, 'stress reduction' and 'attention restoration' demonstrating and explaining these impacts, are well established (reviewed by Bratman et al., 2012). Three pioneering studies attempted to explore the relationship between biodiversity and well-being, which is closer to the objectives of this study. All three studies demonstrated some inconsistent and contradicting results (Fuller et al., 2007; Luck et al., 2011; Dallimer et al., 2012). Better understanding the subconscious impact of interacting with biodiversity remains an important challenge in urban conservation. This study could not help bridge this gap, since if respondents unconsciously received benefits from the increase in biodiversity, they would not have been able to report it in the biodiversity perception items we used. Future experimental research should further aim to explore how increasing biodiversity influence subjective well-being or other physiological proxies of it. However, we would like to argue that while subconscious benefits could influence the way people benefit from biodiversity, they may only have limited impacts on the way people value biodiversity and their willingness to conserve it.

We therefore believe that it is important to conserve and enhance the interaction between biodiversity and people and encourage participation through local conservation education activities (Shwartz et al., 2012; Standish et al., 2012). The establishment of meaningful and lasting people–biodiversity interactions in cities requires that planners and researchers acknowledge the fact that people experience nature differently than ecologists. More experimental interdisciplinary studies are needed to further explore the emerging people–biodiversity paradox (Fuller and Irvine, 2010; Dallimer et al., 2012), whereby people appreciate biodiversity and claim to benefit from it, but show poor capabilities to experience this diversity. These studies should simultaneously sample several aspects of biodiversity and develop rigorous social surveys to measure subjective well-being, targeting different groups of people and cultures in both the developed and developing world.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2014.01.009.

References

Allum, N., Sturgis, P., Tabourazi, D., Brunton-Smith, I., 2008. Science knowledge and attitudes across cultures: a meta-analysis. Public Understand. Sci. 17, 35–54.

Bratman, G.N., Hamilton, J.P., Daily, G.C., 2012. The impacts of nature experience on human cognitive function and mental health. Ann. N. Y. Acad. Sci. 1249, 118–136.

Burnham, K.P., Anderson, D.R., 2002. Model Selection and Multimodel Inference: A Practical Information-theoretic Approach, third ed. Springer, New-York.

Caula, S., Hvenegaard, G.T., Marty, P., 2009. The influence of bird information, attitudes, and demographics on public preferences toward urban green spaces: the case of Montpellier, France. Urban Forest. Urban Green. 8, 117–128.

Clergeau, P., Mennechez, G., Sauvage, A., Lemoine, A., 2001. Human perception and appreciation of birds: a motivation for wildlife conservation in urban environments of France. In: Marzluff, J.M., Bowman, R., Donnlley, R. (Eds.), Avian ecology and conservation in an urbanizing world. Kluwer Academic Publishers, London.

Colwell, R.K., Mao, C.X., Chang, J., 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology 85, 2717–2727.

Dallimer, M., Irvine, K.N., Skinner, A.M.J., Davies, Z.G., Rouquette, J.R., Maltby, L.L., Warren, P.H., Armsworth, P.R., Gaston, K.J., 2012. Biodiversity and the feel-good factor: understanding associations between self-reported human well-being and species richness. Bioscience 62, 47–55.

Davies, Z.G., Fuller, R.A., Loram, A., Irvine, K.N., Sims, V., Gaston, K.J., 2009. A national scale inventory of resource provision for biodiversity within domestic gardens. Biol. Conserv. 142, 761–771.

Day, T.D., 1995. Bird species composition and abundance in relation to native plants in urban gardens, Hamiltonn, New Zealand. Notorins 42, 175–186.

Dearborn, D.C., Kark, S., 2010. Motivations for conserving urban biodiversity. Conserv. Biol. 24, 432–440.

Fontana, S., Sattler, T., Bontadina, F., Moretti, M., 2011. How to manage the urban green to improve bird diversity and community structure. Landscape Urban Plan. 101, 278–285.

Fox, R., 2010. 2009: the year of painted lady. Atropos 40, 1–14.

Fuller, R., Irvine, K.N., 2010. Interactions between people and nature in urban environments. In: Gaston, K. (Ed.), Urban ecology. Cambridge University Press, Cambridge, pp. 134–171.

Fuller, R.A., Irvine, K.N., Devine-Wright, P., Warren, P.H., Gaston, K.J., 2007. Psychological benefits of greenspace increase with biodiversity. Biol. Lett. 3, 390–394.

Fuller, R.A., Warren, P.H., Armsworth, P.R., Barbosa, O., Gaston, K.J., 2008. Garden bird feeding predicts the structure of urban avian assemblages. Diversity and Distributions 14, 131–137.

Gaston, K.J., Smith, R.M., Thompson, K., Warren, P.H., 2005. Urban domestic gardens (II): experimental tests of methods for increasing biodiversity. Biodivers. Conserv. 14, 395–413.

Irvine, K.N., Warber, S., Devine-Wright, P., Gaston, J.K., 2013. Understanding urban green space as health resources: a qualitative comparison of visit motivation and derived effects among park users in Sheffield, UK. Int. J. Environ. Res. Public Health 10, 417–442.

Jokimäki, J., 1999. Occurrence of breeding bird species in urban parks: effects of park structure and broad-scale variables. Urban Ecosyst. 3, 21–34.

Kaufmann, J.C., 2011. L'entretien Comprehensive. Armand Colin, Paris.

Lindemann-Matthies, P., Bose, E., 2007. Species richness, structural diversity and species composition in meadows created by visitors of a botanical garden in Switzerland. Landscape Urban Plan. 79, 298–307.

Lindemann-Matthies, P., Bose, E., 2008. How many species are there? public understanding and awareness of biodiversity in Switzerland. Human Ecol. 36, 731–742.

Lindemann-Matthies, P., Junge, X., Matthies, D., 2010. The influence of plant diversity on people's perception and aesthetic appreciation of grassland vegetation. Biol. Conserv. 143, 195–202.

Luck, G.W., Davidson, P., Boxall, D., Smallbone, L., 2011. Relations between urban bird and plant communities and human well-being and connection to nature. Conserv. Biol. 25, 816–826.

Matsuoka, R.H., Kaplan, R., 2008. People needs in the urban landscape: analysis of landscape and urban planning contributions. Landscape Urban Plan. 84, 7–19.

Matteson, K.C., Langellotto, G.A., 2010. Determinates of inner city butterfly and bee species richness. Urban Ecosyst. 13, 333–347.

Matteson, K.C., Langellotto, G.A., 2011. Small scale additions of native plants fail to increase beneficial insect richness in urban gardens. Insect Conserv. Divers. 4, 89–98.

Miller, J.R., Hobbs, R.J., 2002. Conservation where people live and work. Conserv. Biol. 16, 330–337.

Mayer, I., Slotta-Bachmayr, L., 2005. Imparting of informations in the zoo – how efficient are the standard signs. Zool. Garten 75, 253–265.

Newton, I., 1994. The role of nest sites in limiting the numbers of hole-nesting birds – a review. Biol. Conserv. 70, 265–276.

Paulhus, D.L., 1991. Measurement and control of response bias. In: Robinson, J.P., Shaver, P.R., Wrightsman, L.S. (Eds.), Measures of Social Psychological Attitudes. Academic Press, San Diego, pp. 17–59.

Pyle, R.M., 1978. The extinction of experience. Horticulture 56, 64–67.

Rattray, J., Martyn, J.C., 2007. Essential elements of questionnaire design and development. J. Clin. Nurs. 16, 234–243.

Royan, C., Roth, C.L., 1998. Des plantes utiles aux abeilles. Association de Développement de l'Apiculture d'Île-de-France, 33.

Sadler, J., Bates, A., Hale, J., James, P., 2010. Bringing cities alive: the importance of urban green spaces for people and biodiversity. In: Gaston, K.J. (Ed.), Urban Ecology. Cambirdge University Press, Cambridge, pp. 172–201.

Shwartz, A., 2012. The interaction between people and biodiversity in the heart of a large metropolis. LADYSS, CRBPO. Université de Paris1 Panthéon-Sorbonne. Muséum National d'Histoire Naturelle, Paris.

Shwartz, A., Cheval, H., Simon, L., Julliard, R., 2013a. Virtual garden – a novel tool exploring which biodiversity people want to have in cities. Conserv. Biol. 27, 876–886.

Shwartz, A., Cosquer, A., Jaillon, A., Piron, A., Julliard, R., Raymond, R., Simon, L., 2012. Urban biodiversity, city-dwellers and conservation: how does an outdoor activity day affect the human–nature relationship? PLoS One 7, e328642.

Shwartz, A., Muratet, A., Simon, L., Julliard, R., 2013b. Local and management variables outweigh landscape effects in enhancing the diversity of different taxa in a big metropolis. Biol. Conserv. 157, 285–292.

Simon, L., Goeldner-Gianella, L., 2012. Quelle biodiversité pour quels habitants dans la trame verte urbaine ? L'exemple du Val Maubuée (Seine-et-Marne, France). Développement durable et territories. <http://developpementdurable.revues.org/9326>.

Standish, R.J., Hobbs, R.J., Miller, J.R., 2012. Improving city life: options for ecological restoration in urban landscapes and how these might influence interactions between people and nature. Landscape Ecol. 28, 1213–1221.

Strohbach, M.W., Haase, D., Kabisch, N., 2009. Birds and the city: urban biodiversity, land use, and socioeconomics. Ecol. Soc., 14.

Tanner, T., 1980. Significant life experiences: a new research area in environmental education. J. Environ. Educ. 11 (20), 24.

TEEB (The Economics of Ecosystems and Biodiversity), 2011. TEEB Manual for Cities: Ecosystem Services in Urban Management. <http://www.teebweb.org/> (Accessed July 2012).

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kazmierczak, A., Niemela, J., James, P., 2007. Promoting ecosystem and human health in urban areas using green Infrastructure: a literature review. Landscape Urban Plan. 81, 167–178.

Wu, J., 2010. Urban sustainability: an inevitable goal of landscape research. Landscape Ecol. 25, 1–4.