Chapter 8.

Gardens and plant biodiversity:

Noah's Ark or mixed blessing?

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Introduction

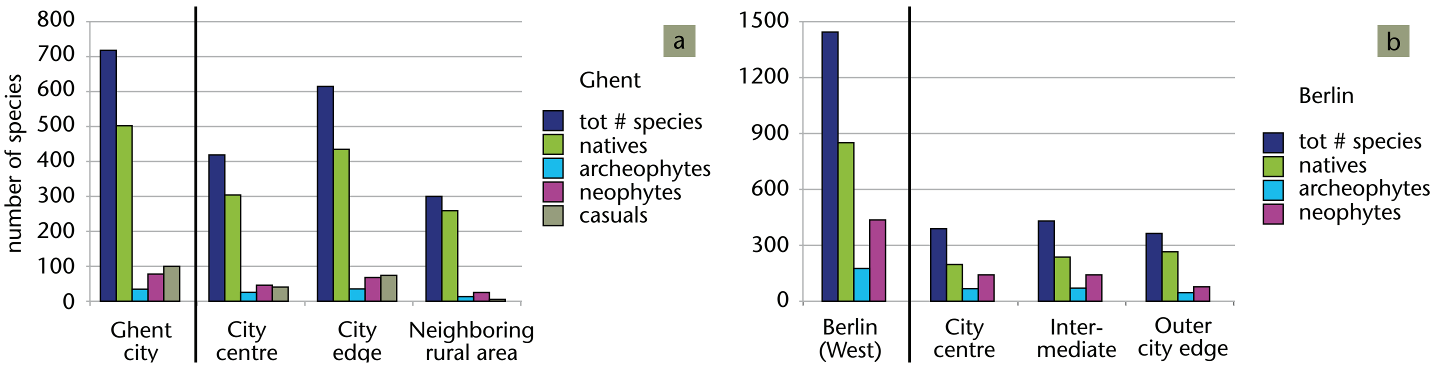
Residential areas have long been viewed as impoverished ecosystems. The assumption was that they only contain exotic species (mainly plants), which survive due to intensive care from the owners. Moreover access to private gardens is difficult, which makes them less convenient for ecological research. So gardens have long been neglected in the scientific-ecological literature (despite some exceptions, Owen, 1991). Indirectly however, the potential value of gardens in biodiversity conservation has long been recognized, as suggested by the abundance of popular books and media interest. The ecological interest in urban areas is, however, much older. Particularly in Germany there has been and continues to be a lively interest in urban ecology (Sukopp, 1990, 2002). Most of this work has described the spontaneous flora, including both native and naturalized species, but has focused on public places or on derelict land. However, as the pressure on nature continuously increases, cities expand and more and more areas become urbanized, the scientific interest in private gardens grows. Recently, and particularly in the United Kingdom, a series of papers has focused on the biodiversity found in gardens (see further). The results were quite astonishing. Urban gardens contain an unexpectedly high diversity of species, both indigenous and exotic. A substantial fraction of the natural flora of a region occurs in gardens. This all suggests that gardens, and cities in general, may act as a Noah's Ark for plant species, in contrast to the cultivated rural landscape in which biodiversity continues to decrease. Although in urban ecology it was common knowledge that urban areas and particularly the edges of cities contained much more species than the cultivated rural areas (Kowarik, 1990), the UK work has been one of the first to show the biodiversity role of gardens so explicitly.

In this chapter we intend to elaborate on the idea of gardens as a Noah's Ark for biodiversity. We look at both the number of species in gardens and their characteristics. Because gardens are an important part of urban areas, we start with the general role of cities in the conservation of biodiversity and then focus on gardens. Examples are drawn from international literature as well as from recent research in Flanders. We focus on the diversity of plant species.

Biodiversity in urban areas

The number of spontaneously surviving plant species in cities is impressive (Figures 8.1 and 8.2). The majority of them are native species, but a considerable portion is naturalized. These naturalized species make the cities quite distinctive from rural areas. The number of introduced and naturalized species may be as much as 50% of the total spontaneous flora (average: 36.8% of which 12.5% archeophytes and 24.3% neophytes) in European cities (Hermy, 2005). The total plant species richness shows a distinctive pattern, with the largest number of species found at the edges of the cities. Contrary to expectations, the number of species in the neighboring rural areas may be lower than in the inner city (Figure 8.1a). As expected, the number of species increases with the size of the city (Figure 8.2a). The increase in the number of neophytes is much larger than the increase of the number of archeophytes (Figure 8.2b). The global result is that cities do contain more spontaneous plant species compared to the countryside despite the large reduction in total vegetation cover and the significant fragmentation of its habitats. These patterns have not only been shown for Berlin or Ghent but also for many other cities in Europe. So it seems that city-edges are hotspots for the richness of (plant) species and show clear gradients from the city edge to the highly build-up center and towards the

Figure 8.1 The number of spontaneous plant species in a gradient from the city centre towards the countryside in Ghent (a) (Hermy & De Blust 1997) and Berlin (b) (Kowarik 1990). Species categories: total number of spontaneous plant species, the number of native plant, the number of archeophytes, the number of neophytes and the number of casuals.



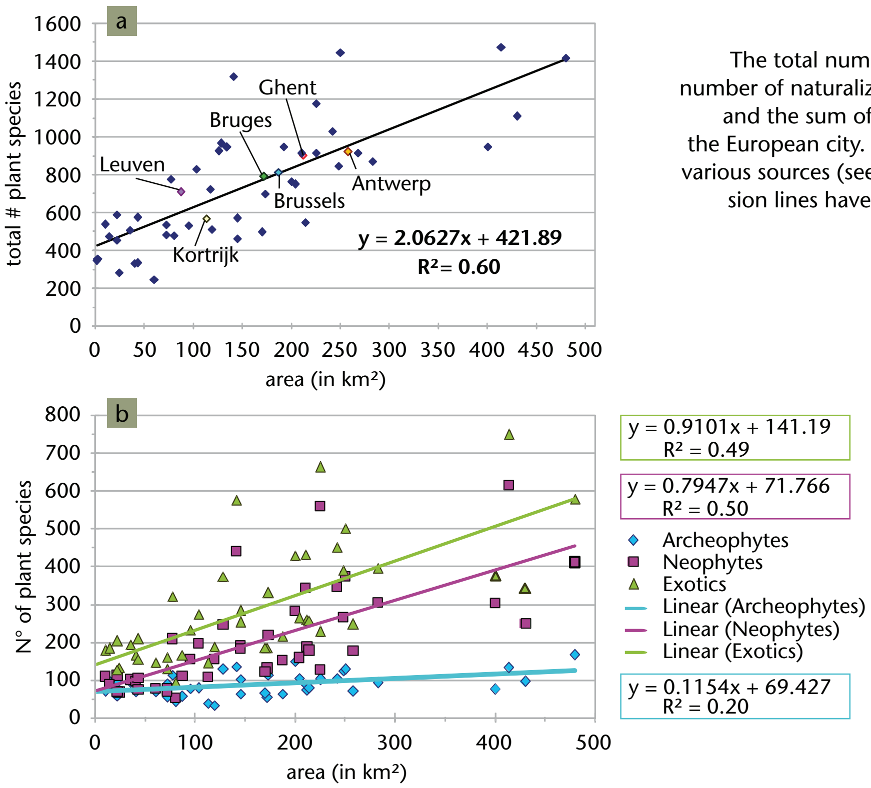


Figure 8.2
The total number of spontaneous plant species (a), the number of naturalized species (b) (archeophytes, neophytes and the sum of these = exotics) in relation to the size of the European city. Each symbol represents a city; data from various sources (see Hermy, 2005). Best fitting linear regression lines have been added. Smallest area was 1.5 km².

surrounding rural areas. Although not widely studied, there are indications that the number of indigenous plant species decreases over time, in contrast to the stable or increasing number of neophytes (Jackowiak, 1990; Pyšek et al., 2004).

Main characteristics of gardens

Domestic gardens contribute substantially to urban green space. Loram et al. (2007) found, for five cities in the United Kingdom (see further), that domestic gardens constitute between 18% and 27% of the urban area; similar contributions were found in other cities (Greater London Area (UK) 19.7%; Dunedin (NZ) 36%; Stockholm (SE) 16%, cities in Flanders (B) 21.6%; Goode, 2006; Colding et al., 2006; Loram et al., 2007; Dewaelheyns et al., 2009). The garden area constitutes typically between 36% and 47% of total urban green space, indicating their importance as a backbone of urban green space. But in contrast to their importance, gardens belong to one of the least studied habitats in urban areas (Mathieu et al., 2007).

Davies et al. (2009) provided key data for domestic gardens in the United Kingdom. Using 12 datasets, both including urban and rural areas, they found an average garden size of 190 m^2 which extrapolates to a total area of 432,924 ha or 1.8% of the total area of the UK. In Flanders the area of gardens is estimated at 8.2% of the total area (Chapter 3). These few examples show that gardens in densely populated countries occupy a substantial area. However, little data are available and the estimates of garden area usually include not only the area covered by plants, but also hard infrastructure such as garden sheds, greenhouses and covered surface areas such as pavement and decking. Based on five cities (Edinburgh, Belfast, Leicester, Oxford & Cardiff), Loram et al. (2007) found that mean garden areas ranged from 155.4 to 253.0 m^2. In Flanders the average garden area was estimated to be 571 m^2, but there was a very large range (10 m^2-23,021 m^2) (Dewaelheyns et al., 2009). Furthermore there was also a clear relation between garden size and housing type in Flanders. Gardens smaller than 100 m^2 were usually associated with row houses; semi-detached houses frequently had a garden area between 250-499 m^2 and the detached houses had the largest gardens of between 500-750 m^2 (Chapter 3). A similar relationship was found in the UK (Loram et al., 2007) and for Mediterranean gardens in France (Marco et al., 2008). Loram et al. (2007) found that detached houses had, on average, a larger garden area (365 m^2) than the semi-detached houses (214 m^2), which in turn had about twice the garden area of row houses. Loram et al. (2007) also found that, on average, rear gardens were twice as large as front gardens. When the front and rear gardens from all the cities were combined, mean areas were 79.5 ± 81.5 m^2 and 41.8 ± 41.9 m^2, respectively. But front gardens increasingly seem headed for neglect and oblivion. Front gardens, which are the face of a neighborhood (Chapter 11) mainly due to their visibility from the roads, are being replaced at an alarming rate by parking places for cars. This is a response to the increase in car ownership and to on-street parking restrictions. Moreover, paving requires much less maintenance than green front yards (Alexander, 2006).

There are 2.5-3.5 million ponds (10% of almost 23 million households) in UK gardens and a staggering 28.7 million trees (54% of all gardens had at least one tree) (Davies et al., 2009). In a nation-wide questionnaire in Australia, NGIA (2009) found that more than half of the Australian gardens contain a lawn (86%), trees (86%), borders (71.8%) and a landscaped garden (54.2%). Compared with the childhood of the respondents (≥18 years), the number of lawns (+6%), vegetable gardens (+20%) and borders (+8%) increased while the proportion of landscaped gardens and the number of outdoor water features decreased.

Gardens may also be regarded as socio-ecological constructions. Several studies have found a correlation between socio-economic status and wildlife (in particular bird populations: Loss et al., 2009). The per capita income of the dwelling occupants was inversely related to the richness of native bird species and positively related to exotic richness. Loss et al. (2009) also found that the median age of the houses was strongly related to avian species richness, with newer neighborhoods supporting more species. The 'mimicry' effect, the fact the planting and landscaping of neighboring gardens tends to be similar, has been described (Zmyslony & Gagnon, 1998) concerning front gardens in Vancouver, but may well go beyond these easily visible garden parts. Gardens in a given neighborhood tend to be more similar to each other than to those in other areas, and this may positively affect the connectivity between gardens, which is an essential feature for wildlife and for a successful dispersal.

Habitat diversity in gardens

Within the project of Loram et al. (2007), Loram et al. (2008) also studied the variation in land-cover types within 267 rear gardens from 5 cities in the UK. They distinguished between 18 land-cover types including the lawn, borders, trees, paths, ponds, greenhouses and sheds… (see also above). Not all 18 types were found in every garden. Patios (surfaces paved in stone or similar hard surfaces) were found in 93% of all gardens, borders were present in 87%, lawns in 78%, sheds in 60% and trees in 55% of all gardens. The diversity of land-cover types per garden ranged from 1 to 12 across all the gardens in the study sample (overall mean = 5.9 ± 2.4) and this was positively correlated with garden areas in all cities. The study showed that the larger the garden, the larger the habitat diversity. As could be expected, there was also a relationship to housing type. Detached houses had the highest land-cover richness and the lowest level was found to be associated with row houses. The structural diversity of the tree and shrub cover in gardens increased significantly according to both the garden area and the number of trees taller than 3 m. The average rear garden was almost 200 m^2 in size (Table 8.1).

Where they occurred, land-covers such as lawns, patios, cultivated (e.g. borders) and uncultivated areas, vegetable patches, gravel and bark surfaces and decking, occupied the largest area (Loram et al., 2008). Overall, the area of the rear garden proved to be the key factor in determining the internal composition and variation of domestic gardens in the UK and there are no indications that would lead one to believe that this is different elsewhere.

From this overview it is clear that gardens typically contain a number of habitats, ranging from hard surfaces, possibly with some planted containers, ponds, borders, and lawns, to individual trees. Given the high number of gardens and their large collective size, gardens may play a key role in offsetting some of the effects of urbanization and may offer a number of ecosystem services. This certainly also holds for front gardens as they act as a buffer against environmental nuisance of roads and traffic. At the same time, they are the part that is visually accessible to the public.

Garden species diversity

Research on private gardens started with long-term studies of single gardens (Owen, 1991). Only recently has data been collected

Table 8.1 Land-cover types recorded in domestic gardens in five UK cities (data from Loram et al., 2008). (a) Frequency with which different land-cover types have been found; (b) The area (mean ± standard error SE) of each land-cover type within the same gardens.

(a) Rear garden	All cities (n=5) Frequency (%)	(b) Area of land-cover type	All houses (m^2)	±SE
Patio	93	Garden area	195.5	11.4
Cultivated border	87	Patio	38.6	1.9
Patio & cultivated border	82	Mown grass	85.5	7.2
Mown grass (lawn)	78	Shed	6.7	0.4
Patio, cultivated border & mown grass	66	Path	17.1	1.3
Shed	60	Compost	2.1	0.4
Trees > 3m	55	Gravel/back chipping	20.4	3
Path (hard, grass, loose)	47	Decking	14.2	1.9
Uncultivated (neglected)	34	Pond	4.6	0.6
Compost (bins & heaps)	33	Other features	4.2	1.1
Gravel/bark	25	Greenhouse	5.8	0.5
Pond	21	Garage	18.4	1.1
Vegetable patch	20	Water butt	1.1	0.1
Other features	19			
Greenhouse	18			
Internal linear feature (m)	16			
Garage	12			
Water butt	12			
Decking (terraces made of wood)	10			
Unmown grass	9			

more systematically, mainly in the UK (e.g. BUGS projects – Thompson et al., 2003, 2004; Loram et al., 2008). These studies in particular revealed detailed data, which forms the main body of evidence put forward here (but see Marco et al., 2008 for Mediterranean gardens). The most unique and widely-known study is probably that of Owen (1991). Jennifer Owen studied the diversity of plant and animal species in her suburban garden of 741 m² over a fifteen-year period between 1972 and 1986. She found over 2,000 species in total (1,757 animal and 422 plant species), representing about 20% of the total species richness of Great Britain and that just for a garden of less than one 1,000 m²! However, one should keep in mind that not all these species were recorded at the same time. Two studies from nature-like gardens in Flanders (Hermy & De Blust, 1997) found a lower number of species – collected over a shorter period – yet still making up about 20 to 40% of the regional species diversity (Table 8.2).

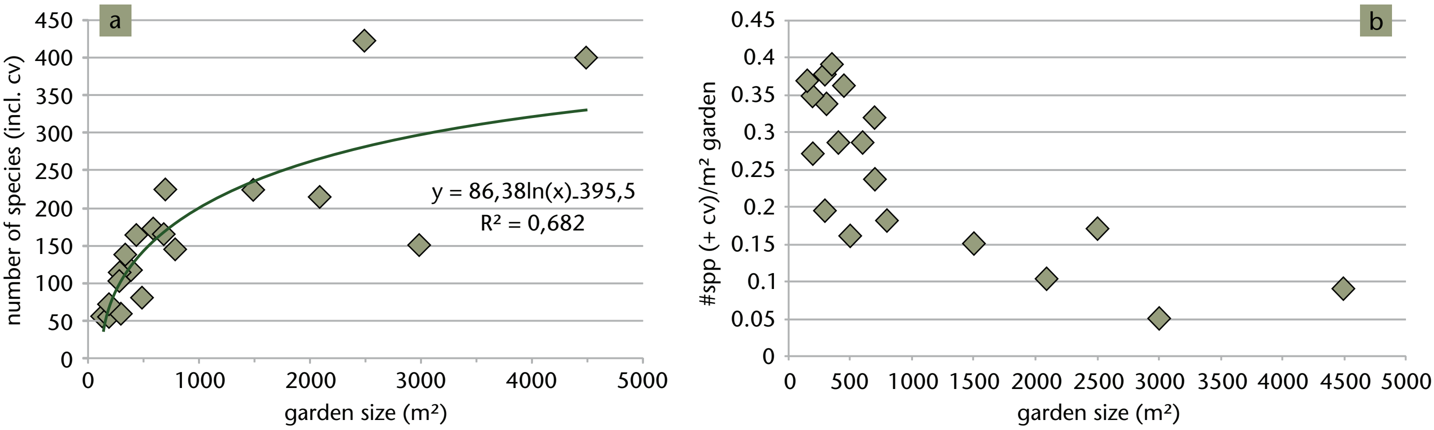
In the UK, Loram et al. (2008) investigated the number of plant species in 267 urban

Table 8.2 The total number of species found in two natural gardens in Flanders (Hermy & De Blust, 1997).

(a) a ten year old garden in Wetteren (size: 5,000m²)			
taxa	n° of spp. in garden	n° of spp. in Flanders	% of spp. in gardens vs. Flanders
Butterflies	19	47	40
Dragon flies	15	32	47
Total number of species	**34**	**79**	**43**
(b) a six year old garden in Hasselt (size: 6,500m²)			
taxa	n° of spp. in garden	n° of spp. in Flanders	% of spp. in gardens vs. Flanders
Vascular plants	265	1,279	21
Butterflies	12	47	26
Dragon flies	13	32	41
Grasshoppers	8	32	25
Spiders	89	550	16
Total number of species	**387**	**1,940**	**20**

domestic gardens in the five cities mentioned above, using a complete census and a quadrat sampling design. The entire flora consisted of 1,056 species, of which 30% were native and 70% alien (see also Smith et al., 2006). 34% of the 50 most frequently recorded species in gardens were native, a number of them being weeds. Although plant species richness in individual gardens varied with garden area, there was surprisingly little difference in plant species richness, diversity or composition between the cities, despite their variation in geographical and climatic factors. This suggests that human factors such as plant availability, garden management and the social/economic status of individual gardeners had an overriding influence on biodiversity. The latter was also found in a study of 19 gardens in Belgium (Claessens, unpublished). Here the number of plant species was not related to soil variables (such as pH) when controlling for garden size. The species number increased with garden size, but species density decreased with garden area (Figure 8.3a,b; see also Smith et al., 2006) suggesting that gardeners tend to pack their gardens with plants primarily chosen for their aesthetic characteristics, such as flower color, and texture. Therefore it seems that plant selection, even among experienced gardeners, is not usually driven by the ecological (mainly soil) conditions available in gardens. There was also a marginally significant positive correlation with the amount of maintenance (Figure 8.4a), although maintenance per m² decreased as garden size increased (Figure 8.4b). Figure 8.4a suggests that plant survival in gardens mainly depends on maintenance and not on a clear match between species composition and site conditions. Yet this

Figure 8.3 Relationships between garden size and the total number of taxa found (a) and the number of taxa per m² garden (b) in 19 gardens in Flanders.



match between plants and site conditions is a key characteristic of sustainable gardens.

Garden area also proved to be positively correlated with the diversity in habitats (or land-cover types, see Table 8.1) and diversity in vegetation structure (Loram et al., 2008). This diversity may also positively affect wildlife diversity. Osborne et al. (2008) consider gardens in urban and suburban areas as a refuge for bumblebees. They compared nest densities in gardens and countryside habitats in the UK. They found that nest densities were high in gardens (36 nests ha^{-1} or one nest in every two

Figure 8.4 Maintenance in 19 gardens of experienced gardeners in Flanders. Maintenance increases as the number of taxa (species and cultivars) increases (a) (Spearman rank correlation = 0.31, P = 0.10, excluding a nursery garden) , but maintenance per m² decreases as garden size increases (b).

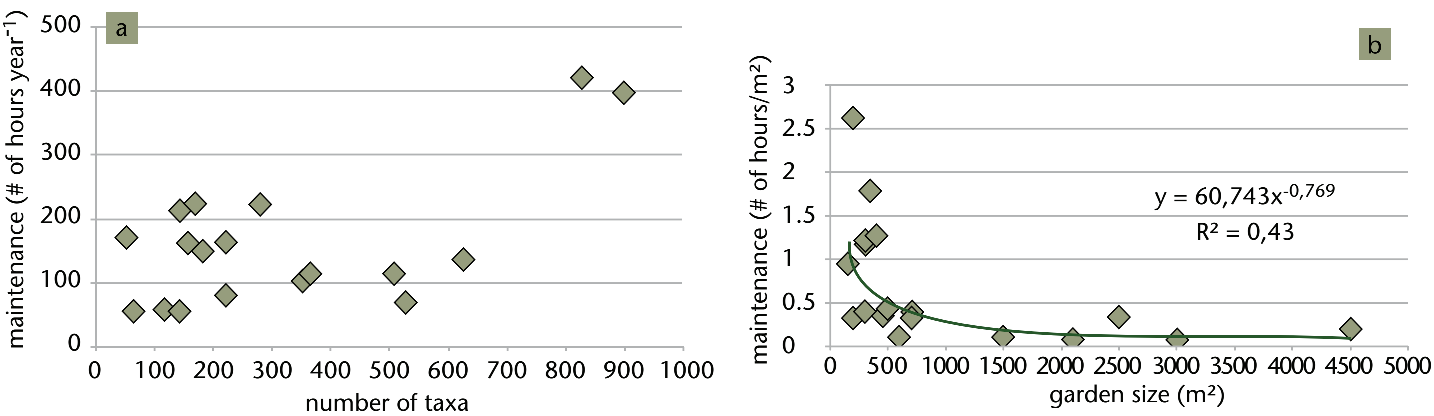
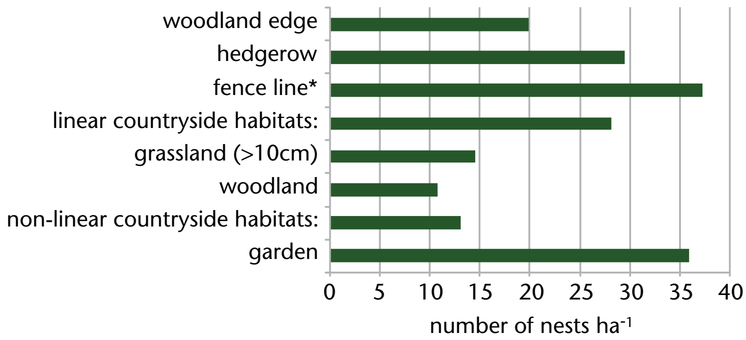


Figure 8.5
Bumblebee nest density (nest ha^{-1}) found in seven habitats surveyed in the UK in June & July 2004 (drawn from data in Osborne et al., 2008).



gardens), higher than in non-linear countryside habitats (woodland and grassland: 11-15 nests ha^{-1}). For linear countryside habitats densities were comparable to that of gardens (Figure 8.5). The number of bumblebee nests per unit area did not differ significantly between large (> 450 m^2), medium and small (< 100 m^2) gardens. Within gardens, compost heaps/bins or bird nesting boxes were the most attractive locations to bumblebees and had significantly more nests than lawns or flowerbeds. The high density found in gardens may be attributed to the diversity of garden features and gardening styles which provides a large variety of potential nesting sites compared to the more homogeneous non-linear countryside habitats. Areas with gardens indeed do have high concentrations of boundary features, such as hedges, fences, and garden sheds, which are suitable for nesting. In addition the extension of the flowering period, a common priority for gardeners, ensures a continuous supply of nectar and pollen throughout spring and summer (Osborne et al., 2008).

So all of the studies seem to suggest that gardens may be hotspots of diversity and of considerable conservation interest, despite the large proportion of alien plant species in gardens. As we are faced with a new biodiversity crisis, which impacts heavily on rural areas, one might therefore suggest that domestic gardens serve as a Noah's Ark. However, many of these species are aliens (do we need to conserve exotic species in their introduced range?), have extremely small population sizes, and are significantly isolated from one another, which makes them very vulnerable to local extinction. A number of native species frequently occur in gardens, yet these are also generally quite common overall. This seems to indicate that gardens may not be able to safeguard biodiversity for the long term.

From a landscape ecological point of view, cities and gardens are characterized by habitat patches that are small, fragmented and isolated. The role of gardens in this landscape ecological network is still unclear, although for mobile species this ecological patchwork may be functional. Evans et al. (2009) reviewed 72 studies about the influence of habitat on urban birds and concluded (i) that local factors are more important than regional ones in determining the species richness; (ii) that habitat fragmentation frequently influences urban avian assemblages, with the effects of patch size being greater than those of isolation, and (iii) that urban bird assemblages appear to respond positively to increasing structural complexity, species richness of woody vegetation, and supplementary feeding, but negatively to human disturbance. For less mobile species, however, these factors can be expected to be entirely different.

Conservation: scaling up from garden to cityscape

To assess the role of gardens in conserving biodiversity, research should be scaled up from the level of the garden to the level of the cityscape. Small individual gardens can form a larger habitat network that interferes with the surrounding landscape. The integration of the design and management of individual, private gardens into citywide biodiversity strategies is equally needed (Goddard et al., 2009). One might also question the cumulative outcome of individual garden-scale management decisions since most private householders lack the necessary skills and experience in biodiversity conservation (this is called the tyranny of small decisions by Goddard et al., 2009). A further concern may be the significant presence of alien plant species in gardens. Given the area of gardens and the diversity of alien species used, it is very likely that gardens constitute the largest source of alien plant species with the potential to colonize other habitats (Smith et al., 2006). Lambdon et al. (2008) found that ornamental and horticultural introductions accounted for 52.2% of the total number of naturalized aliens (3,749 spp.) in Europe. Horticultural plants have exerted a major influence as invasive species in the world (Smith et al., 2006). The diversity of alien plant species grown in gardens may thus be a considerable danger (see also Niinemets & Penuelas, 2007), but also offers a potential benefit in view of climate change (Van der Veken et al., 2008). 'New' species may be viewed as an enrichment of the local biodiversity and key elements in maintaining ecosystem services (see also Walther et al., 2009). So it seems that the high diversity of species in gardens may be a mixed blessing.

Yet it is definitely clear that gardens are extremely important constituents of the urban green space. Currently, gardens are an important hotspot for plant biodiversity, forming a patchy network of island habitats of considerable overall importance to a city and its inhabitants.

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