Planning for the Future of Urban Biodiversity: A Global Review of City-Scale Initiatives

CHARLES H. NILON, MYLA F. J. ARONSON, SAREL S. CILLIERS, CYNNAMON DOBBS, LAUREN J. FRAZEE, MARK A. GODDARD, KAREN M. O'NEILL, DEBRA ROBERTS, EMILIE K. STANDER, PETER WERNER, MARTEN WINTER, AND KEN P. YOCOM

Cities represent considerable opportunities for forwarding global biodiversity and sustainability goals. We developed key attributes for conserving biodiversity and for ecosystem services that should be included in urban-planning documents and reviewed 135 plans from 40 cities globally. The most common attributes in city plans were goals for habitat conservation, air and water quality, cultural ecosystem services, and ecological connectivity. Few plans included quantitative targets. This lack of measurable targets may render plans unsuccessful for an actionable approach to local biodiversity conservation. Although most cities include both biodiversity and ecosystem services, each city tends to focus on one or the other. Comprehensive planning for biodiversity should include the full range of attributes identified, but few cities do this, and the majority that do are mandated by local, regional, or federal governments to plan specifically for biodiversity conservation. This research provides planning recommendations for protecting urban biodiversity based on ecological knowledge.

Keywords: biodiversity conservation, ecosystem services, urban planning, policy regulation, governance

Globally, towns and cities are rapidly increasing in area and in population; urban area is projected to triple until 2030 (Batty 2008, Seto et al. 2012). Most urbanization is occurring in regions identified as biodiversity hotspots (Seto et al. 2012), with profound effects on ecological patterns and processes, including habitat destruction, degradation, and fragmentation; changes to biological assemblages resulting in novel ecological communities; increased levels of pollution in soil, air, and water systems; and alterations of natural disturbance regimes and ecosystem processes, such as water and nutrient cycling (Luck 2007, Grimm et al. 2008). As a result, (a) the density of flora and fauna is substantially reduced in urban areas compared with that in nonurban habitats (Aronson et al. 2014), and (b) urban floras become more similar over time (La Sorte et al. 2014). Reductions in biodiversity decrease the capacity of ecosystems to capture essential resources, produce biomass, and maintain ecological processes such as nutrient cycling (Cardinale et al. 2012). Reductions in urban biodiversity have consequences for human well-being, reducing the benefits people can obtain from nature at individual and community levels (Brown and Grant 2005, Fuller and Irvine 2010, Luck 2012). However, recent research has shown that cities can still support significant levels of biodiversity, including endangered and threatened species, and therefore can play an important role in biodiversity conservation (Aronson et al. 2014, Ives et al. 2015).

People experience biodiversity primarily where they live. Urban planning and policy therefore have the potential to influence how people and communities experience and understand biodiversity, as well as to increase support for conservation in the city and beyond (Dearborn and Kark 2010, Karvonen and Yocom 2011). Daily interaction with nature engages people in nature conservation (Fuller and Irvine 2010) and has positive effects on physical and psychological health, social cohesion, crime reduction, environmental awareness, economic gain, and sense of belonging (Giles-Corti et al. 2005, Barton and Pretty 2010).

Biodiversity conservation in cities works to preserve remnant natural habitats while further planning, designing, and implementing green-infrastructure networks. Green infrastructure across the city allows for a diversity of natural, restored, and constructed habitats that all serve to improve conditions for biodiversity in public and private lands (Beninde et al. 2015). For example, private gardens constitute an important group of microhabitats that foster a large diversity of flora and fauna that residents can directly experience (Smith et al. 2006, Loram et al. 2008). Efficient

BioScience XX: 1–11.
doi:10.1093/biosci/bix012 Advance Access publication XX XXXX, XXXX

planning and management can increase biodiversity and improve conditions for urban areas within this green-infrastructure network (Irvine et al. 2010).

Biodiversity also contributes to a city's capacity to adapt to changing environmental conditions by maintaining ecosystem health (Díaz et al. 2006, Tzoulas et al. 2007, Haines-Young and Potschin 2010). One way of representing the benefits of biodiversity for the environment and for humans is the concept of ecosystem services (MEA 2005), describing the benefits that humans derive from nature. The biophysical structure and function of ecosystems are linked to services, which are then linked to human well-being through benefits and economic value (Hansen and Pauleit 2014). Conserving and fostering biodiversity also support the continuity of these ecosystem processes, including the maintenance and enhancement of human well-being (Cardinale et al. 2012, Sandifer et al. 2015). Although there is large and increasing body research on ecosystem services in cities, the findings are not often used by city planners (Ahern et al. 2014, Haase et al. 2014).

Biodiversity conservation and managing for ecosystem services present conservation challenges for planning and policy (Dearborn and Kark 2010). Although cities are centers of consumption and land-use change, they represent a considerable opportunity for forwarding global sustainability and environmental goals. For example, cities are at the forefront in planning for climate-change adaptation and mitigation (Rosenzweig et al. 2010), and research into urban-ecosystems dynamics are revealing the potential for managing local and large-scale environmental change (Youngsteadt et al 2014).

City plans and biodiversity: Questions and approaches

Researchers studying how cities address planning for biodiversity and ecosystem services have focused on case studies of individual cities (e.g., McPhearson et al. 2014, Kabisch 2015). Here, we examine how multiple cities plan for and address issues of biodiversity conservation and ecosystem services. We are interested in understanding how such planning and implementation can simultaneously serve as drivers to enhance biodiversity conditions within cities as well as barriers. We examine city plans, policies, and strategies from the perspective of the ecological sciences by identifying important attributes for urban biodiversity and ecosystem services at a global scale. Our research represents a first step in understanding how the urban-planning process can be used to address biodiversity conservation and the provision of ecosystem services. We do not address important questions about plan implementation or about the success of the plans in conserving species or in the provision of ecosystem services. Instead, we ask three questions: (1) What are the biodiversity and ecosystem-services attributes that are relevant for urban planning? (2) Which of these attributes do cities include in their plans? (3) How do cities differ in their use of these attributes? More specifically, do biodiversity and ecosystem-services plan attributes differ between cities located in biodiversity hotspots (Conservation International 2016) and those that are not located in biodiversity hotspots? And do the biodiversity and ecosystem-services plan attributes in cities participating in the City Biodiversity Index (CBI; Chan and Djoghlaf 2009) differ from those in other cities?

We sampled 40 cities from 25 countries. We wanted to understand how cities from a variety of ecological, political, and economic contexts incorporated biodiversity and ecosystem services into planning. Cities were initially identified from previous global studies of urban biodiversity and green infrastructure (Aronson et al. 2014, Dobbs et al. 2014). To be included in the sample, the city had to have at least one official planning document that contained a goal that was specifically related to biodiversity or related ecosystem services. To broaden the geographic range, we sought recommendations from ecologists and urban planners for cities in Africa, South America, and Southeast Asia that were not included in Aronson and colleagues' (2014) and Dobbs and colleagues' (2014) studies. The sample of cities included all biogeographic realms (excluding Antarctica) and 34 ecoregions (table 1).

Between January and December 2014, we conducted online searches and talked with city employees or consultants to identify 135 city- or metropolitan-scale plans from the 40 selected cities. The online search was initiated with the name of the city and the keywords *biodiversity*, *ecosystem services*, *open space*, *green space*, *conservation*, *sustainability*, *street trees*, *climate change*, *comprehensive plan*, and *green infrastructure*. We examined official city websites to identify additional relevant documents. The majority of the plans were written in English, but plans in Portuguese, Spanish, Dutch, German, French, Chinese, and Italian were also evaluated by coders with proficiency in these languages.

Biodiversity and ecosystem-services attributes

We identified 34 attributes that are important to urban planning for biodiversity conservation and related ecosystem services on the basis of a comprehensive literature review (table 2). These attributes were organized into six categories: baseline data, biodiversity goals, biodiversity targets, ecosystem-services goals, ecosystem-services targets, regulations, and commitment to implementation (table 2). *Biodiversity goals* were defined as objectives related to biodiversity conservation: habitats, species, monitoring of biodiversity, connectivity among parcels of land, green infrastructure, invasive-species management, education, stewardship (i.e., encouraging citizen involvement), and constructed habitats (e.g., green roofs and bioswales). *Ecosystem-services goals* were defined as those whose planning or implementation directly benefits biodiversity. We chose the most common ecosystem-services goals that are addressed in city plans according to the plans we assessed: air and water quality, carbon sequestration, urban-heat-island amelioration, urban agriculture, and cultural services (e.g., recreation or fostering

Table 1. The population, biogeographic characteristics (World Wildlife Fund Ecoregions), presence in biodiversity hotspots, ratification of the Convention on Biological Diversity, and number of plans for each city. See the supplemental material for plan references.

Cities	Population (thousands)	Reference	Hotspot	Ecoregion	CBD	Number of plans
Amsterdam	1057	UN		Atlantic mixed forests	×	2
Baltimore	2207	UN		Southeastern mixed forest		1
Berlin	3475	UN		Central European mixed forests	×	4
Bogota	8506	UN	×	Magdalena Valley montane forests	×	3
Brussels	1958	UN		Atlantic mixed forests	×	2
Cape Town	3345	UN	×	Lowland fynbos and renosterveld	×	5
Chicago	8616	UN		Central forest–grassland transition		2
Christchurch	356	UN	×	Centerbury–Otago tussock grasslands	×	4
Curitiba	3118	UN	×	Araucaria moist forests	×	3
Durban	2739	UN	×	South Africa mangroves	×	2
Frankfurt	681	UN		Western European broadleaf forests	×	3
Hamburg	1785	UN		Atlantic mixed forests	×	3
Hamilton	203	NZ Stats	×	Bermuda subtropical conifer forests	×	5
Ho Chi Minh City	6189	UN	×	Southeastern Indochina dry evergreen forests	×	2
Hong Kong	7050	UN	×	South China–Vietnam evergreen forests	×	1
Iquitos	435	UN		Iquitos varze	×	1
Johannesburg	7992	UN	×	Highveld grasslands	×	1
Lisbon	2034	UN	×	Southwest Iberian Mediterranean Sclerophyllus and mixed forest	×	2
London	9699	UN		English lowland beech forests	×	12
Melbourne	3951	UN		Southeast Australia temperate forests	×	6
Mexico City	20132	UN	×	Central Mexican matorral	×	7
Monrovia	1264	UN	×	Western Guinean lowland forests	×	2
Nagoya	9165	UN	×	Taiheiyo evergreen forests	×	3
Nairobi	3915	UN		Northern Acacia–Commiphora bushlands and thickets	×	1
Nelson Mandela Bay Municipality	1139	South African cities network	×	Albany thickets	×	1
New York	18365	UN		Northeastern coastal forests		1
Phoenix	3649	UN		Sonoran desert		4
Porto Alegre	3476	UN	×	Uruguayan savanna	×	3
Potchefstroom	250	www.potch.co.za		Highveld grasslands	×	1
Rome	3592	UN	×	Italian sclerophyllus and semideciduous forest	×	2
San Diego	2964	UN	×	Californian coastal sage and chaparral		3
Santiago	6269	UN	×	Chilean matorral	×	4
Seoul	9796	UN		Central Korean deciduous forests	×	1
Sheffield	682	UN		Celtic broadleaf forests	×	4
Singapore	5079	UN	×	Peninsular Malaysian rain forests	×	3
St Louis	2153	UN		Central forest–grassland transition		3
Stockholm	1360	UN		Sarmatic mixed forest	×	2
Vancouver	2278	UN		Puget lowland forests	×	4
Warsaw	1703	UN		Central European mixed forests	×	2
Washington DC	4604	UN		Southeastern mixed forest		11

Table 2. Biodiversity and ecosystem-services attributes coded from 135 plans in 40 cities globally. See the supplemental material for references.

Attribute	Code	Definition	References
Baseline data	CityDa	Does the plan use baseline data collected from within the city?	Hermy and Cornelis 2000, Cilliers et al. 2004
	DataHab	Does the plan use baseline data on habitats?	Drewes and Cilliers 2004, Holmes et al. 2012
	DataSpp	Does the plan use baseline data on species?	Farina-Marques et al. 2011, Rebelo et al. 2011, Bekessy et al. 2012
Biodiversity goals	BioGoal	Does the plan have specific and/or general (i.e., protect biodiversity, ecology, species, habitats, natural resources, plants, animals, and genetic resources) biodiversity goals?	
	BioConn	Specific reference to corridors, increasing connectivity for ecological purposes, or creating a green network.	Mörtberg et al. 2007, Beninde et al. 2015
	BioSpp	Specific species or mention of native or indigenous species or archaeophytes (in Europe only).	McKinney 2002, Rebelo et al. 2011, Holmes et al. 2012
	BioHab	Conserve, restore, maintain, or manage habitats of forest, grasslands, wetlands, woodlands, and open space. Mention of specific habitats.	Margules and Pressy 2000, Rebelo et al. 2011, Sætersdal and Gjerde 2011, Holmes et al. 2012, Lindenmayer et al. 2014, Beninde et al. 2015
	BioEd	Formal and informal education, outreach, and interpretation related to biodiversity conservation.	McKinney 2002, Miller and Hobbs 2002, Dearborn and Kark 2009, Goddard et al. 2010, Kabish 2015
	BioStew	Encourage volunteer groups, nongovernmental organizations, community engagement, and citizen science related to biodiversity conservation.	Savard et al. 2000, Miller and Hobbs 2002, Dearborn and Kark 2009, Goddard et al. 2010, Holmes et al. 2012
	BioMon	Species and habitat monitoring, ecological research, and adaptive management.	Noss 1990, Turner et al. 2003
	BioInv	Management of invasive alien species and reduction in invasive species.	Pysek 1998, Chambers et al. 1999, von der Lippe and Kowarik 2008, Aronson and Handel 2011
	BioCon	Constructed habitats: bioswales, greenroofs, greenstreets, rain gardens, and gardens or yards.	Lyle 1997, Margolis and Robinson 2007, Oberndorfer et al. 2007, Ignatieva et al. 2011, MacIvor and Lundholm 2011, Rottle and Yocom 2011, Chiquet et al. 2013, Braaker et al. 2014
Biodiversity targets	TarSpp	Quantitative targets for increasing populations of species identified by the plan for conservation.	Berke and Godschalk 2009
	TarHab	Quantitative targets for increasing habitat area identified by the plan for conservation.	
	TarBio	Quantitative targets for particular taxa: 11 groups—plants, mammals, birds, reptiles, amphibians, fish, molluscs, butterflies, other arthropods, fungi, and bats—identified for conservation.	
	TarInv	Quantitative targets for decreasing invasive, alien, and nonnative species.	
	TarCrit	Quantitative targets for increasing critical biodiversity habitats.	
	TarBuilt	Quantitative targets for constructed habitats: bioswales, greenroofs, greenstreets, rain gardens, and gardens or yards (often called green infrastructure in the United States).	
	TarOth	Other quantitative targets related to biodiversity.	
Ecosystem-services goals	ESS Goals	Does the plan have specific and/or general ecosystem-services goals?	
	EssH20	Does the plan have goals for increasing water quality and flood retention, including stormwater, freshwater wetlands, lakes, salt marshes, floodplains, and riparian areas?	Cardinale 2011, Balvanera et al. 2013, Ahern et al. 2014
	ESSAir	Does the plan have goals for increasing tree cover for air-pollution removal?	Nowak et al. 2006, Manes et al. 2012, Ahern et al. 2014
	ESSCar	Are tree-planting efforts or the conservation of forests mentioned for carbon-storage or -sequestration purposes?	Balvanera et al. 2013 Hooper et al. 2012 Tilman et al. 1997, McPherson et al. 2008, Pincetl et al. 2013, Ahern et al. 2014
	ESSUHI	Are tree-planting efforts or the conservation of forests mentioned for climate amelioration or urban heat islands?	McPherson et al. 2008, Pramova et al. 2012, Pincetl et al. 2013, Ahern et al. 2014
	ESSAgr	Does the plan include food production, urban gardens, or urban agriculture?	Ahern et al. 2014, Bernstein 2014, Potter and LeBuhn 2015
	ESScul	Are there biodiversity-conservation, -habitats, or -communities goals specifically for sense of place, education, stewardship, or recreation?	Gill et al. 2009, Pickett et al. 2011, Ahern et al. 2014

Table 2. Continued.

Attribute	Code	Definition	References
Ecosystem-service targets	TarH20	Quantitative targets for the reduction in water pollutants or increase in wetland habitat.	Berke and Godschalk 2009
	TarAir	Quantitative targets for the reduction of air pollutants by planting efforts or other conservation efforts.	
	TarCar	Quantitative targets to increase the number of trees or biomass for carbon-storage and -sequestration purposes.	
	TarUHI	Quantitative targets to reduce urban-heat-island effects via tree planting, the conservation of forests, or other conservation efforts.	
	TarAgr	Quantitative targets for food production, urban gardens, and urban agriculture.	
	TarCul	Quantitative targets for biodiversity conservation, habitats, or communities for sense of place, education, and stewardship.	
Commitment to implementation	Commit	Is there some mention of implementation that has happened or will happen (e.g., funds or actions)?	Berke and Godschalk 2009
Regulatory elements	Reg	Are there elements of the plan that are mandated (e.g., laws or ordinances)?	Berke and Godschalk 2009

a sense of place). We also coded regulatory elements indicating that at least one of the biodiversity or ecosystem-services goals or targets in at least one of the city's plans was mandated at the city or regional level, including laws, ordinances, or other governing mechanisms. Finally, implementation elements included sources of funding, timelines, local agencies, or organizations tasked with specific actions that address goals (Berke and Godschalk 2009) and actions to enhance biodiversity, such as ecological restoration or adaptive-management activities.

The selected attributes reflected scientific findings and recognized practices in biodiversity conservation management and planning (table 2). Each plan was assessed and scored for the presence or absence of these attributes. This is a common method used for assessing plan quality across a wide variety of planning domains, and this approach determines whether preselected plan criteria are present in sampled plans (Lyles and Stevens 2014, Stevens et al. 2014). Validity issues related to this method center on the reliability and replicability of the data used for analysis (Berke and Godschalk 2009, Stevens et al. 2014). With 10 investigators conducting assessments, each was trained in attribute definitions. Once compiled, the data were submitted to a rigorous quality-assurance or quality-control process, with each plan reviewed and coded by a second member of the research team.

Principal-component analysis (PCA) was performed to examine how cities differed in planning for biodiversity and ecosystem services on the basis of the scored attributes. We also correlated biodiversity and ESS attributes to PCA axis scores to determine which attributes were associated with any groups of cities that emerge from the analysis.

Cities may differ in external factors that may influence planning for biodiversity and ecosystem services. We used multiresponse permutation procedures (MRPP) to determine whether cities in biological hotspots (Conservation International 2016) were different in plan attributes from those not in hotspots (table 1). We also used MRPP to determine whether cities that have completed a CBI differ in plan attributes from non-CBI cities. The CBI is a series of indicators of biodiversity and ecosystem services developed by the Singapore National Park Board and the Convention on Biological Diversity as a tool to help cities develop biodiversity goals and targets (Chan and Djoghlaf 2009). We used MRPP because it is a robust nonparametric test for comparing groups (McCune and Grace 2002). These analyses were performed in PCORD 6.08 (MjM Software; McCune and Grace 2002).

Phi-correlation analyses were performed on plans to determine whether attributes were correlated with each other within plans. We defined strong correlations as those with a phi coefficient $r_\varphi > .6$ with $p < .0001$ and moderate correlations as those $r_\varphi < .6$ to $r_\varphi > .4$ with $p < .0001$. This analysis was performed in JMP Pro 11.2.0 (SAS Institute, Inc.).

Attributes of biodiversity and ecosystem services addressed in city plans

The most common attribute found in plans was the presence of an ecosystem-services goal. More than 80% of the studied plans incorporated at least one goal for enhancing ecosystem services (figure 1). The majority of plans also included some mention of commitment to implementation, one or more goals for enhancing biodiversity, and, in particular, goals for increasing or improving the quantity or quality of specific habitats. Measurable targets for biodiversity and ecosystem services occurred in a smaller number of plans (figure 1). Correlation analysis revealed which attributes were associated with each other within individual plans (supplemental table S1). The highest correlation values for biodiversity-related attributes ($r_\varphi > .6$, $p < .0001$) were between targets for taxa and targets for specific species and between goals for biodiversity education and

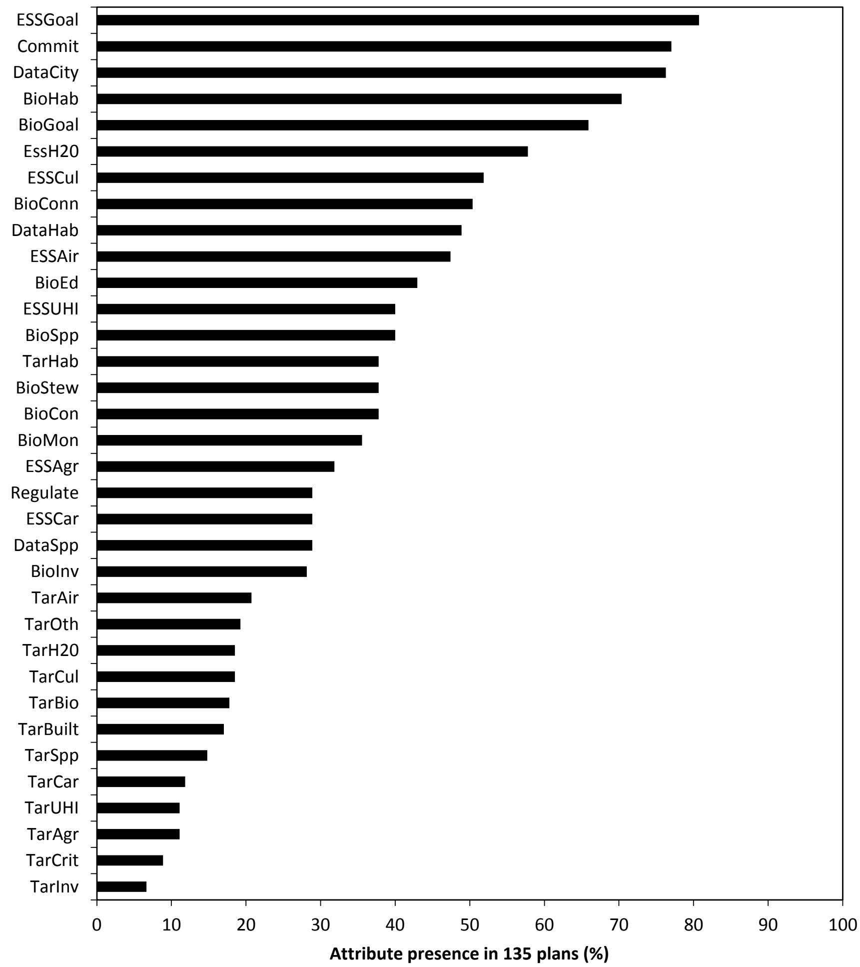

*Figure 1. The presence (%) of biodiversity and related ecosystem-services attributes (***n** *= 34) in 135 plans from 40 cities globally.*

goals for biodiversity stewardship. Biodiversity stewardship and education were moderately correlated ($r_\varphi < .6$ to $r_\varphi > .4$, $p < .0001$) with goals for biodiversity monitoring. Goals for biodiversity stewardship and monitoring were both moderately correlated with goals to control invasive species. Baseline data on habitats were moderately correlated with baseline data on species and goals for ecological connectivity. Baseline data on species were moderately correlated with goals for species conservation. Goals for habitat conservation were moderately correlated with goals to increase ecological connectivity. Specific biodiversity goals were not correlated with specific targets, except for between goals for constructed habitats and targets for constructed habitats ($r_\varphi = .51$, $p < .0001$), as well as goals for habitat conservation and targets for specific habitats ($r_\varphi = .46$, $p < .0001$).

The highest correlation between ecosystem-services attributes was between targets for water quality and targets for air quality ($r_\varphi > .6$, $p < .0001$). Goals for urban agriculture were moderately correlated with goals for water quality and regulation ($r_\varphi < .6$ to $r_\varphi > .4$, $p < .0001$). Goals for air-quality amelioration were moderately correlated with goals for urban-heat-island amelioration and carbon sequestration ($r_\varphi < .6$ to $r_\varphi > .4$, $p < .0001$). Goals and targets for urban-heat-island amelioration were moderately correlated with each other ($r_\varphi = .41$, $p < .0001$). Goals and targets for water quality were moderately correlated to each other ($r_\varphi < .40$, $p < .0001$). In general, biodiversity goals and targets were not correlated with ecosystem-services goals and targets (table S1).

Differences in how cities address biodiversity and ecosystem services

The cities with the highest number of attributes related to biodiversity in their plans were Washington, DC (94% of biodiversity attributes), followed by Baltimore, London, Mexico City, Nagoya, Seoul, and Sheffield (83% of biodiversity attributes). The cities with the fewest attributes for biodiversity were Hong Kong, Ho Chi Minh City, Monrovia, and Iquitos. The cities with the highest number of attributes for ecosystem services in their plans were Washington, DC; London; New York; Berlin; Baltimore; Hamburg; Vancouver; and Ho Chi Minh City. The cities with the fewest attributes ecosystem services were Seoul, Nairobi, and Potchefstroom, the latter two having none at all (figure 2).

Ten principal components (eigenvalues more than or equal to 1.0) explained 76.3% of the variation among the cities. The first component explained 20% of the variance, with no loadings more than or equal to 0.5 or less than –0.5. The second principal component explained an additional 12.7% of the variance, with no loadings more than or equal to 0.5 or less than –0.5 (figure 3). The PCA graph shows that the cities are separated by the presence or absence of biodiversity and ecosystem services in their plans. The graph is characterized by a separation of cities with biodiversity and ecosystem-services goals and targets from those that do not incorporate these attributes into their plans. The bi-plots in the graph show biodiversity and ecosystem-services attributes that indicated plan attributes associated with the first two principal component axes ($R^2 > 2.50$). Vector lengths indicate the strengths of the individual attributes (McCune and Grant 2002). Cities in the upper left quadrant of the graph had plans that incorporated baseline data on habitats; biodiversity goals for connectivity, education, and monitoring; plan implementation for invasive species; and ecosystem-services goals for cultural ecosystem services. Cities in the lower left quadrant of the graph have plans with ecosystem-services targets for agriculture, heat islands, air quality, and carbon

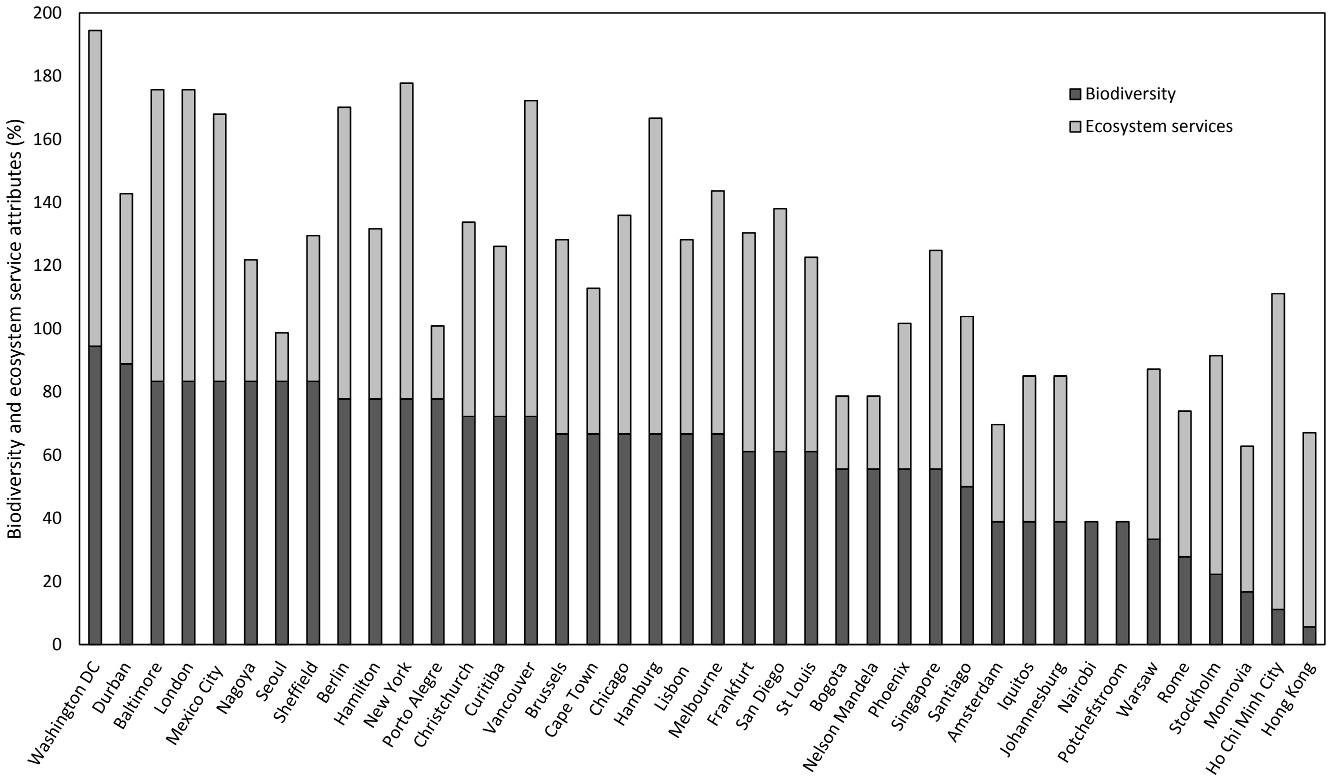

Figure 2. The distribution of the biodiversity and ecosystem-services attributes for 40 cities globally.

storage, as well as ecosystem-services goals for air quality. Cities to the right of the figure did not feature these attributes in their plans.

Cities in biodiversity hotspots were not significantly different in the biodiversity and ecosystem-services attributes their plans addressed from cities not in hotspots (MRPP: T = –0.80, A = 0.0006, $p = .19$). In addition, cities in hotspots were not different from cities not in hotspots when examining only the 18 biodiversity (T = –1.49, A = 0.01, $p = .08$) or the 13 ecosystem-services attributes (T = –0.60, A = 0.008, $p = .23$). Cities that have participated in the CBI were not significantly different in the biodiversity and ecosystem-services attributes they addressed in their plans from cities that have not participated in the CBI (T = 0.54, A = –0.004, $p = .67$). When we examined only the 18 biodiversity attributes or only the ecosystem-services attributes, cities that have participated in the CBI were not significantly different from those cities that have not (biodiversity MRPP: T = –0.08, A = 0.0009, $p = .39$; ecosystem services MRPP: T = 0.97, A = –0.01, $p = .85$).

Planning for biodiversity and ecosystem services: Context matters

The ecological and societal values of biodiversity and ecosystem services in cities are becoming an important component of urban socioecological research and city agendas (Dearborn and Kark 2010). We have identified 34 biodiversity and ecosystem-services attributes that are relevant to and part of contemporary approaches to urban planning. The 34 attributes that we defined followed the guidelines for a comprehensive plan as defined by the American Planning Association (APA 2006) by emphasizing goal setting, analyzing existing conditions and trends, describing a future vision for the community, and outlining policies and guidelines for implementing that vision. The biodiversity attributes were within the scope of the ICLEI Biodiversity Planning guidelines, which focus on documenting current actions; assessing the current state of biodiversity; planning for the integration of biodiversity goals, objectives, and actions; and plan implementation, monitoring, and review. The ecosystem-services attributes are within the scope of The Economics of Ecosystems and Biodiversity (TEEB) stepwise approach to planning, which identifies which ecosystem services are relevant to policy, defines information needs, and assesses ecosystem services (Margules and Pressey 2000, APA 2006, TEEB 2010, ICLEI–Local Governments for Sustainability 2015).

Community engagement appears to be an important component of most plans. Plans that included community engagement in some form (i.e., education and citizen science) are present for the majority of cities (figure 1). Combined occurrence of goals for stewardship, education, and monitoring indicate citizen involvement that goes beyond traditional planning. Additional correlations of these variables with goals for connectivity and targets for taxonomic groups may be explained by the observation that volunteers often deal

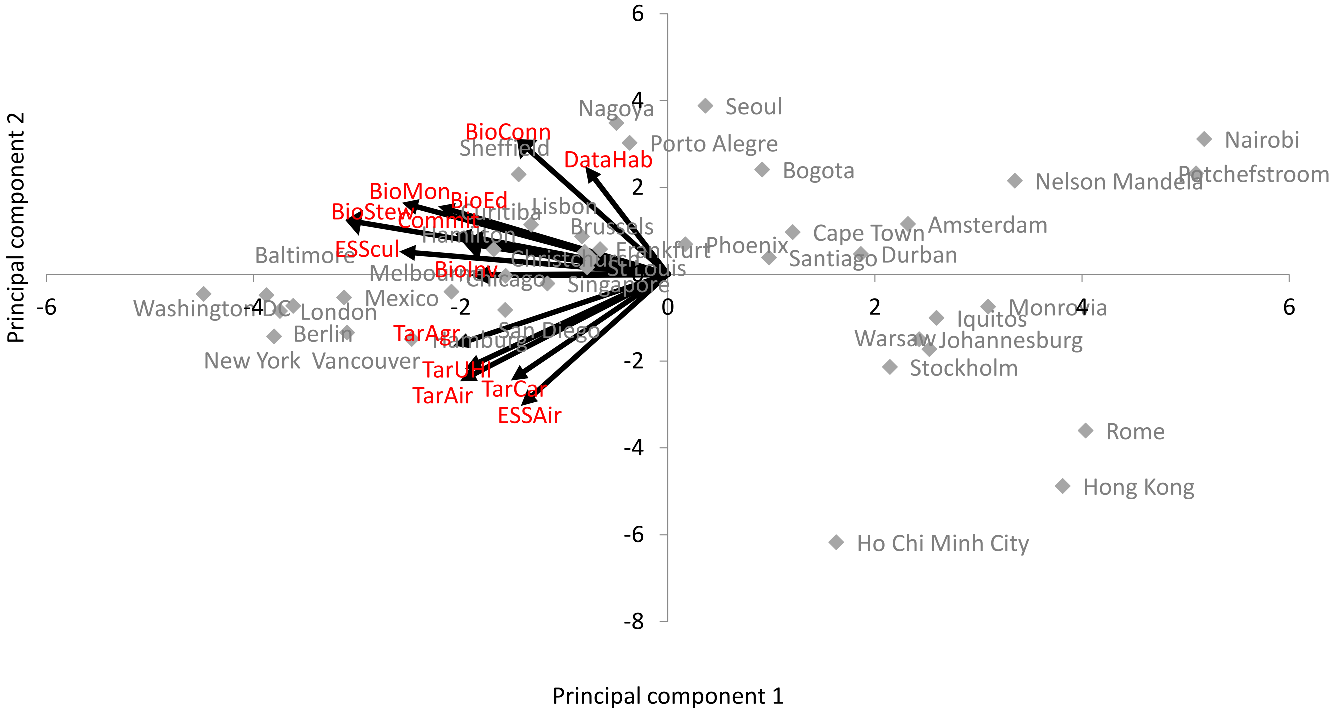

Figure 3. Principal components 1 (20%) and 2 (12.7%) for the biodiversity and ESS attributes included in city plans. The arrows corresponded to the attributes correlated with PCA axis 1 and 2 (Pearson correlation; r > .05).

with specific taxonomic groups, such as birds, amphibians, or orchids, and are frequently involved in monitoring projects for nature conservation (Schmeller et al. 2009, Tanadini and Schmidt 2011). Only if monitoring data are available is it possible to define measurable targets compared with the baseline. Although there is some overlap in the actions and targets dealt with in these documents, they do include several policies and some planning decisions to be able to reach the targets (e.g., Mayor of London 2010, 2011).

Despite the importance of targets for determining whether planning goals were achieved (Berke and Godschalk 2009), we found a lack of targets in these plans. Fact-based urban plans are more successful, because they allow for an analysis of current conditions and for tracking changes and setting measurable targets to assess improvement of the effectiveness of urban plans (Berke and Godschalk 2009). The lack of targets may reflect the strategic focus of many plans (APA 2006) or may be a response to the political structure or climate within cities where conflicts between environmental and development goals could lead to caution in assigning targets that may lack political support (Freund 2001, Evans 2004, Holmes et al. 2012). Examples of the inclusion of such data in planning are urban biotope mapping, which includes all land uses (Drewes and Cilliers 2004); systematic biodiversity planning, which focuses on fragmented natural areas (Rebelo et al. 2011, Holmes et al. 2012); and using the biodiversity costs of an area to determine trade-offs between conservation and development (Bekessy et al. 2012).

Some cities already have access to baseline data gathered by universities or government agencies. However, Evans (2004, 2006) described gaps in the data collected by scientists and volunteer naturalists and problems in incorporating these data into local plans. Washington, DC; Berlin; and London are examples that such gaps can be closed more or less sufficiently and that baseline data help to define targets. For example, of the plans that addressed ecosystem services from London, United Kingdom, the focus was on regulating services (air quality, water quality, and urban heat islands; Mayor of London 2010, 2011). This may be the result of a long history of research on air quality and air pollution, and plans even include studies showing the importance of trees in removing atmospheric particulate pollution (e.g., Tallis et al. 2011). There are also several networks in London linking scientists, policymakers, and urban residents, such as the Air Pollution Research in London (APRIL) network (*www.april-network.org/home*), which might indicate a closer and more direct link between scientists, stakeholders, and the public.

Many cities possess detailed information about habitats developed from biotope- or habitat-mapping projects (Werner 1999, Jarvis and Young 2005), as well as systematic conservation plans (figure 1; Rebelo et al. 2011, Holmes et al. 2012). Habitat targets are easier to set than species targets, in part because gathering habitat data is faster and less expensive than collecting species data, which usually requires taxonomic experts (Danielsen et al. 2005). Habitat data were often used in identifying sites for conservation planning. At first glance, it is surprising that few plans set targets for nature-conservation areas. This may be because regional- or national-level governments typically have authority over the most important nature-conservation areas (Margules and Pressey 2000, Dacorum 2006). In addition, special plans for single conservation areas, where targets may be specified, were not included in our investigation.

Cities differed in both the number of attributes they included in their plans as well as the combination of attributes. Cities typically included either biodiversity or ecosystem services but were rarely comprehensive in both. The attributes cities include in their plans may be related to mandates by the country, region, or city itself. Among the cities with the largest number of attributes in their plans, Washington, DC; Berlin; and London are mandated to combine planning functions of city and regional or subnational state governments. Their expanded planning roles include Washington, DC, having a state's responsibility for developing a State Wildlife Action Plan (Michalak and Lerner 2008, Fontaine 2011), Berlin having detailed environmental data and plans required of German states (Schneider et al. 2007), and the Greater London Authority having detailed natural-resources plans for 36 local governments (Goode 1989). Other cities with a large number of scored attributes incorporate biodiversity or ecosystem services into sustainability plans. For instance, Baltimore's sustainability plan is comprehensive, addressing biodiversity, ecosystem services, and social goals, although it has less detail than Washington, DC; London; and Berlin (which approaches its sustainability similarly; Senatsverwaltung für Stadtentwicklung und Umwelt 2012). In addition, Vancouver's sustainability plan—a combined effort of Environment Canada, the British Columbia Provincial Government, and local government—addresses sustainability issues within a larger regional context.

Plans also reflect local circumstances (Evans 2004). For example, Cape Town has a systematic conservation plan with targets and planning for natural areas, habitats, and fragmented natural areas, but it does not focus on ecosystem services. Cape Town has an active conservation department, a strong history of research and data on fragmented natural areas, and a commitment to national biodiversity initiatives (Holmes et al. 2012, O'Farrell et al. 2012). Another example is Ho Chi Minh City in Vietnam, where the uncontrolled urbanization and the flat and low-lying topography make the city vulnerable to the influences of climate change (Eckert and Voigt 2008). Therefore, the adaptation plan for the city focused on six strategic directions that included aspects such as water storage and quality, flood protection, groundwater use, and the urban-heat-island effect, each with specific interventions. Distinct targets were identified within each direction with short-term (until 2025), midterm (until 2050), and long-term (until 2100) goals (Ho Chi Minh City 2013). Finally, plans may reflect individuals or groups that champion biodiversity, such as Durban, South Africa (Freund 2001). Champions may rally people to action, but efforts may be at risk if a champion leaves the scene (Box et al. 1994, Roberts and Diederichs 2002, Lachmund 2013).

Ultimately, understanding the diversity of approaches to planning for biodiversity and ecosystem services in cities requires research into each city's experience in the development, use, and implementation of plans. Further insight into urban biodiversity and ecosystem planning can be achieved by understanding the processes and mechanisms that lead to specific planning approaches. Studying the ecological setting, the social and political planning context, and the roles of actors and champions for plans is crucial in understanding the paths chosen by local governments. In this way, we can begin to understand how cities can integrate biodiversity conservation in an increasingly urban world.

Supplemental material

Supplementary data are available at *BIOSCI* online.

Acknowledgments

This article is a joint effort of the working group of listed authors and an outcome of workshops kindly supported by the National Socio-Environmental Synthesis Center (SESYNC) under funding received from the National Science Foundation no. DBI-1052875, and supported by sDiv, the Synthesis Centre of the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig (no. DFG FZT 118). Additional support is from the US National Science Foundation (NSF RCN: DEB no. 1354676/1355151) and the US Department of Agriculture's National Institute of Food and Agriculture under the Hatch program (no. NJ26125). We received assistance with the translation of some documents from Ines Cabral and Cecilia Herzog.

References cited

Ahern J, Cilliers SS, Niemela J. 2014. The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. Landscape and Urban Planning 125: 254–259.

[APA] American Planning Association. 2006. Planning and Urban Design Standards. Wiley.

Aronson MFJ, et al. 2014. A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. Proceedings of the Royal Society B 281 (art. 20133330).

Barton J, Pretty J. 2010. Urban ecology and human health and wellbeing. Pages 202–229 in Gaston KJ, ed. Urban Ecology. Cambridge University Press.

Batty M. 2008. The size, scale and shape of cities. Science 319: 769–771.

Bekessy SA, White M, Gordon A, Moilanen A, Mccarthy MA, Wintle BA. 2012. Transparent planning for biodiversity and development in the urban fringe. Landscape and Urban Planning 2–4: 140–149.

Beninde J, Veith M, Hochkirch A. 2015. Biodiversity in cities needs space: A meta-analysis of factors determining intra-urban biodiversity variation. Ecology Letters 18: 581–592.

Berke P, Godschalk D. 2009. Searching for the good plan: A meta-analysis of plan quality studies. Journal of Planning Literature 23: 227–240.

Box J, Douse A, Kohler T. 1994. Non-statutory sites of importance for nature conservation in the West Midlands. Journal of Environmental Planning and Management 37: 361–367.

Brown C, Grant M. 2005. Biodiversity and human health: What role for nature in healthy urban planning? Built Environment 31: 326–338.

Cardinale BJ, et al. 2012. Biodiversity loss and its impact on humanity. Nature 486: 59–67.

Chan L, Djoghlaf A. 2009. Invitation to help compile an index of biodiversity in cities. Nature 460: 33.

Conservation International. 2016. The Biodiversity Hotspots. Conservation International, Critical Ecosystem Partnership Fund. (25 January 2017; *www.cepf.net/resources/hotspots/Pages/default.aspx*)

[Dacorum] Dacorum Borough Council. 2006. Urban Nature Conservation Study. Hertfordshire Biological Records Centre. (2 May 2016; *www.dacorum.gov.uk/docs/default-source/planning-development/uncsmar06.pdf*)

Danielsen F, Burgess ND, Balmford A. 2005. Monitoring matters: Examining the potential of locally-based approaches. Biodiversity and Conservation14: 2507–2542.

Dearborn DC, Kark S. 2010. Motivations for conserving urban biodiversity. Conservation Biology 24: 432–440.

Díaz S, Fargione J, Chapin FS III, Tilman D. 2006. Biodiversity loss threatens human well-being PLOS Biology 4 (art. e277). doi:10.1371/journal.pbio.0040277

Dobbs C, Nitschke CR, Kendal D. 2014. Global drivers and tradeoffs of three urban vegetation ecosystem services. PLOS ONE 9 (art. e113000).

Drewes JE, Cilliers SS. 2004. Integration of urban biotope mapping in spatial planning. Town and Regional Planning 47: 15–29.

Eckert R, Voigt C. 2009. Developing guidelines for energy and climate efficient urban structures: A new planning instrument for adapting Ho Chi Minh City to the impacts of climate change. Paper presented at the Fifth Urban Research Symposium; 28–30 June 2009, Marseille, France. (25 January 2017; *www-docs.tu-cottbus.de/megacity-hcmc/public/04_Conferences/2009_URS_Eckert.pdf*)

Evans J. 2004. What is local about local environmental governance? Observations from the local biodiversity action planning process. Area 36: 270–279.

Evans JP. 2006. Lost in translation? Exploring the interface between local environmental research and policymaking. Environment and Planning A 38: 517–531.

Fontaine JJ. 2011. Improving our legacy: Incorporation of adaptive management into state wildlife action plans. Journal of Environmental Management 92: 1403–1408.

Freund B. 2001. Brown and green in Durban: The evolution of environmental policy in a post-apartheid city. International Journal of Urban and regional Research 25: 717–739.

Fuller RA, Irvine KN. 2010. Interactions between people and nature in urban environments. Pages 134–171. Gaston KJ, ed. Urban Ecology. Cambridge University Press.

Giles-Corti B, Broomhall MH, Knuiman M, Collins C, Douglas K, Ng K, Lange A, Donovan RJ. Increasing walking: How important is distance to, attractiveness, and size of public open space? American Journal of Preventive Medicine 28: 169–176.

Goode DA. 1989. Urban nature conservation in Britain. Journal of Applied Ecology 263: 859–873.

Grimm NB, Faeth SH, Golubiewski NE, Redman CL, Wu J, Bai X, Briggs JM. 2008. Global change and the ecology of cities. Science 319: 756–760.

Haase, D, Haase A, Rink D. 2014. Conceptualizing the nexus between urban shrinkage and ecosystem services. Landscape and Urban Planning 132: 159–169.

Haines-Young R, Potschin M. 2010. The links between biodiversity, ecosystem services and human well-being. Pages 110–139 in Raffaelli DG, Frid CLJ, eds. Ecosystem Ecology: A New Synthesis. Cambridge University Press.

Hansen R, Pauleit S. 2014. From multifunctionality to multiple ecosystem services? A conceptual framework for multifunctionality in green infrastructure planning for urban areas. Ambio 43: 516–529.

Ho Chi Minh City. 2013. Climate Adaptation Strategy Ho Chi Minh City. Vietnam Climate Adaptation PartnerShip (VCAPS) Consortium. (25 January 2017; *www.vcaps.org/assets/uploads/files/HCMC_ClimateAdaptationStrategy_webversie.pdf*)

Holmes PM, Rebelo AG, Dorse C, Wood J. 2012. Can Cape Town's unique biodiversity be saved? Balancing conservation imperatives and development needs. Ecology and Society 17 (art. 28).

[ICLEI] International Council for Local Environmental Initiatives–Local Governments for Sustainability. 2015. BiodiverCITIES: A Handbook for Municipal Biodiversity Planning and Management. ICLEI. (2 May 2016; *www.icleicanada.org/resources/item/221-biodivercities-a-handbook-for-municipal-biodiversity-planning-and-management*)

Irvine KN, Fuller RA, Devine-Wright P, Tratalos J, Payne SR, Warren PH, Lomas KJ, Gaston KJ. 2010. Ecological and psychological value of urban green space. Pages 215–237 in Jenks M, Jones C, eds. Dimensions of the Sustainable City. Springer.

Ives CD, et al. 2016. Cities are hotspots for threatened species. Global Ecology and Biogeography 25: 117–126.

Jarvis PJ, Young, CH. 2005. The Mapping of Urban Habitat and its Evaluation: A Discussion Paper Prepared for the Urban Forum of the United Kingdom Man and the Biosphere Programme. Man and the Biosphere Programme. (2 May 2016; *www.ukmaburbanforum.co.uk/docunents/papers/MABpaper.pdf*)

Kabisch N. 2015. Ecosystem service implementation and governance challenges in urban green space planning: The case of Berlin, Germany. Land Use Policy 42: 557–567.

Karvonen A, K. Yocom K. 2011. The civics of urban nature: Enacting hybrid landscapes. Environment and Planning A 43: 1305–1322.

Lachmund J. 2013. Greening Berlin: The Co-Production of Science, Politics, and Urban Nature. MIT Press.

La Sorte FA, et al. 2014. Beta diversity of urban floras among European and non-European cities. Global Ecology and Biogeography 23: 769–779.

Loram A, Thompson K, Warren PH, Gaston JK. 2008. Urban domestic gardens (XII): The richness and composition of the flora in five UK cities. Journal of Vegetation Science 19: 321–330.

Luck GW. 2007. A review of the relationships between human population density and biodiversity. Biological Reviews 82: 607–645.

Lyles W, Stevens M. 2014. Plan quality evaluation 1994–2012: Growth and contributions, limitations, and new directions. Journal of Planning Education and Research 34: 433–450.

Margules, CR, Pressey, RL. 2000. Systematic conservation planning. Nature 405: 243–253.

Mayor of London. 2010. Clearing the Air: The Mayor's Air Quality Strategy. (25 January 2017; *http://legacy.london.gov.uk/mayor/strategies/energy/docs/energy_strategy04.pdf*)

———. 2011. Securing London's Water Future: The Mayor's Water Strategy. (25 January 2017; *www.london.gov.uk/sites/default/files/water-strategy-oct11.pdf*)

McCune B, Grace JB. 2002. Analysis of Ecological Communities. MjM Software Design.

McPhearson T, Hamstead ZA, Kremer P. 2014. Urban ecosystem services for resilience planning and management in New York City. Ambio 43: 502–515.

[MEA] Millennium Ecosystem Assessment. 2005. Ecosystems and Human Well-Being: Synthesis Report. Island Press.

Michalak J, Lerner J. 2008. Linking conservation and land use planning: Using the State Wildlife Action Plans to protect wildlife from urbanization. Pages 32–40 in Pulugurtha S, O'Loughlin R, Hallmark S, eds. Transportation Land Use, Planning, and Air Quality. American Society of Civil Engineers.

O'Farrell PJ, Andersen PML, LeMaitre DC, Holmes PM. 2012. Insights and opportunities offered by a rapid ecosystem service assessment in promoting a conservation agenda in an urban biodiversity hotspot. Ecology and Society 17 (art. 27).

Rebelo AG, Holmes PM, Dorse C, Wood J. 2011. Impacts of urbanization in a biodiversity hotspot: Conservation challenges in metropolitan Cape Town. South African Journal of Botany 77: 20–35.

Roberts D, Diederichs N. 2002. Durban's Local Agenda 21 programme: Tackling sustainable development in a post-apartheid city. Environment and Urbanization 14: 189–201.

Rosenzweig C, Solecki W, Hammer SA, Shagun M. 2010. Cities lead the way in climate-change action. Nature 467: 909–911.

Sandifer PA, Sutton-Grier AE, Ward BP. 2015. Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. Ecosystem Services 12: 1–15.

Schmeller DS, et al. 2009. Advantages of volunteer-based biodiversity monitoring in Europe. Conservation Biology 23: 307–316.

Schneider T, Goedecke M, Lakes T. 2007. Berlin (Germany) Urban and environmental information system: Application of remote sensing for planning and governance—potentials and problems. Pages 199–219 in Netzband DM, Stefanov DWL, Redman, eds. Applied Remote Sensing for Urban Planning Governance and Sustainability. Springer.

Senatsverwaltung für Stadtentwicklung und Umwelt. 2012. Berliner Strategie zur Biologischen Vielfalt. (2 May 2016; *www.stadtentwicklung.berlin.de/natur_gruen/naturschutz/downloads/publikationen/biologische_vielfalt_strategie.pdf*)

Seto KC, Güneralp B, Hutyra LR. 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. Proceedings of the National Academy of Sciences 109: 16083–16088.

Smith RM, Thompson K, Hodgson JG, Warren PH, Gaston KJ. 2006. Urban domestic gardens (IX): Composition and richness of the vascular plant flora, and implications for native biodiversity. Biological Conservation 129: 312–322.

Stevens MR, Lyles W, Berke PR. 2014. Measuring and reporting intercoder reliability in plan quality evaluation research. Journal of Planning Education and Research 34: 77–93.

Tallis M, Taylor G, Sinnett D, Freer-Smith P. 2011. Estimating the removal of atmospheric particulate pollution by the urban tree canopy of London, under current and future environments. Landscape and Urban Planning 103: 129–138.

Tanadini LG Schmidt BR. 2011. Population size influences amphibian detection probability: Implications for biodiversity monitoring programs. PLOS ONE 6 (art. e28244). doi:10.1371/journal.pone.0028244

[TEEB] The Economics of Ecosystems and Biodiversity. 2010. The Economics of Ecosystems and Biodiversity for Local and Regional Policy Makers. (2 May 2016; *www.teebweb.org/our-publications/teeb-study-reports/local-and-regional-policy-makers/#.Ujr1939mOG8*)

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

Werner P. 1999. Why biotope mapping in populated areas? DEINSEA 5: 9–26.

Youngsteadt E, Dale AG, Terando AJ, Dunn RR, Frank SD. 2015. Do cities simulate climate change? A comparison of herbivore response to urban and global warming. Global Change Biology 21: 97–105.

Charles H. Nilon (NilonC@missouri.edu) is affiliated with the School of Natural Resources at University of Missouri, in Columbia, Missouri. Myla F. J. Aronson is affiliated with the Department of Ecology, Evolution and Natural Resources at Rutgers University, in New Brunswick, New Jersey. Sarel S. Cilliers is affiliated with the School of Environmental Sciences and Development at North-West University, in Potchefstroom, South Africa. Cynnamon Dobbs is affiliated with the Department of Ecosystems and Environment at Pontifical Catholic University of Chile, in Santiago, Chile. Lauren J. Frazee is affiliated with the Department of Ecology, Evolution and Natural Resources at Rutgers University, in New Brunswick, New Jersey. Mark A. Goddard is affiliated with the School of Civil Engineering and Geosciences at Newcastle University, in Newcastle upon Tyne, United Kingdom. Karen M. O'Neill is affiliated with the Department of Human Ecology at Rutgers University, in New Brunswick, New Jersey. Debra Roberts is affiliated with the Sustainable and Resilient City Initiatives Unit at eThekwini Municipality, in Durban, South Africa. Emilie K. Stander is affiliated with the Department of Science and Engineering at Raritan Valley Community College, in North Branch, New Jersey. Peter Werner is affiliated with the Institute for Living and Environment at Research Institute of the State of Hesse and the City of Darmstadt, in Darmstadt, Germany. Marten Winter is affiliated with the Synthesis Center at German Center for Integrative Biodiversity Research, in Leipzig, Germany. Ken P. Yocom is affiliated with the Department of Landscape Architecture at University of Washington, in Seattle, Washington.