Received: 24 April 2020 | Revised: 22 June 2020 | Accepted: 2 July 2020
DOI: 10.1002/ppp3.10143

Plants People Planet PPP Open Access

OPINION

The state of the world's urban ecosystems: What can we learn from trees, fungi, and bees?

Philip C. Stevenson[1,2] | Martin I. Bidartondo[1,3] | Robert Blackhall-Miles[4] | Timothy R. Cavagnaro[5] | Amanda Cooper[1,6] | Benoît Geslin[7] | Hauke Koch[1] | Mark A. Lee[1] | Justin Moat[1] | Richard O'Hanlon[8] | Henrik Sjöman[9,10,11] | Adriano Sofo[12] | Kalliopi Stara[13] | Laura M. Suz[1]

[1]Royal Botanic Gardens, Kew, UK
[2]Natural Resources Institute, University of Greenwich, Chatham, Kent, UK
[3]Life Sciences, Imperial College London, London, UK
[4]FossilPlants, Llanberis, UK
[5]The School of Agriculture, Food and Wine, The Adelaide University, Adelaide, South Australia, Australia
[6]Royal Holloway University of London, Egham, UK
[7]IMBE, Aix Marseille Université, Avignon Université, CNRS, Marseille, France
[8]Agri-Food and Biosciences Institute, Belfast, Antrim, UK
[9]Swedish University of Agricultural Science, Alnarp, Sweden
[10]Gothenburg Botanical Garden, Gothenburg, Sweden
[11]Gothenburg Global Biodiversity Centre, Gothenburg, Sweden
[12]Department of European and Mediterranean Cultures: Architecture, Environment, Cultural Heritage (DiCEM), University of Basilicata, Matera, Italy
[13]Dept of Biological Applications and Technology, University of Ioannina, Ioannina, Greece

Correspondence
Philip C. Stevenson Royal Botanic Gardens, Kew, Surrey TW9 3AB, UK.
Email: p.stevenson@kew.org

Social Impact Statement

Positive interactions between people and nature inspire behaviours that are in harmony with biodiversity conservation and also afford physical and mental health benefits. Since most people live in towns and cities, urban greenspaces are key points of influence for conservation, but also provide diverse ecosystem services. City trees are a foundation for biodiversity in urban ecosystems, and their belowground interactions with mycorrhizal fungi and aboveground interactions with pollinators must be central to urban ecosystem planning. Messaging about biodiversity must be clearer to avoid unintended negative outcomes from conservation actions such as low diversity tree planting and unsustainable levels of urban beekeeping

Summary

Trees are a foundation for biodiversity in urban ecosystems and therefore must be able to withstand global change and biological challenges over decades and even centuries to prevent urban ecosystems from deteriorating. Tree quality and diversity should be prioritized over simply numbers to optimize resilience to these challenges. Successful establishment and renewal of trees in cities must also consider belowground (e.g., mycorrhizas) and aboveground (e.g., pollinators) interactions to ensure urban ecosystem longevity, biodiversity conservation and continued provision of the full range of ecosystem services provided by trees. Positive interactions with nature inspire people to live more sustainable lifestyles that are consistent with stopping biodiversity loss and to participate in conservation actions such as tree-planting and supporting pollinators. Interacting with nature simultaneously provides mental and physical health benefits to people. Since most people live in cities, here we argue that urban ecosystems provide important opportunities for increasing engagement with nature and educating people about biodiversity conservation. While advocacy on biodiversity must communicate in language that is relevant to a diverse audience, over-simplified messaging, may result in unintended negative outcomes. For example, tree planting actions typically focus on numbers rather than diversity while the call to save bees has inspired unsustainable proliferation of urban beekeeping that may damage wild bee conservation through increased competition for limited forage in cities and disease spread. Ultimately multiple ecosystem services must be considered (and measured) to optimize their delivery in urban ecosystems and messaging to promote the value of nature in cities must be made widely available and more clearly defined.

KEYWORDS

city trees, mycorrhizas, nature's contribution to people, regulating ecosystem services, urban beekeeping, urban ecosystems

1 | INTRODUCTION

Human activity has deleterious impacts for life on earth (IPBES, 2019) yet the welfare of people and nature are mutually dependent so transformative change in human activity is required to stop biodiversity loss (Diaz et al., 2019). Conservation of biodiversity can be achieved through more sustainable behaviors that recognize and respond to the consequences of contemporary lifestyles (Allan et al., 2019; Duffy, Godwin, & Cardinale, 2017; Watson & Venter, 2017). One way to do this is to optimize positive interactions with nature as these inspire more sustainable activities with beneficial outcomes for the environment (Alcock, White, Pahl, Duarte-Davidson, & Fleming, 2020). Interactions with nature also improve human mental and physical well-being (Bratman, Daily, Levy, & Gross, 2015; Lawton, Brymer, Cough, & Denovan, 2017; Richardson & McEwen, 2019). Therefore there is much to be gained from enhancing urban ecosystems to change behaviors and inform the public about conservation and their regulating ecosystems services such as cleaner air and water (Hausmann, Petermann, & Rolff, 2016; Sandström, Angelstam, & Mikusiński, 2006; Smith, Warren, Thompson, & Gaston, 2006; Somme et al., 2016). Here we focus on urban ecosystems, defined as the built infrastructure, or as those in which people live at high densities (Pickett, Cadenasso, & Grove, 2001). In particular we refer to urban areas of vegetation when using the term urban ecosystems such as parks, gardens, railway sidings, allotments and waste ground.

Urban ecosystems can be managed to deliver many services, such as provisioning food, inspiring cultural development, regulating local environment (e.g., clean air) or supporting wildlife (Figure 1a). We have a better understanding of some services than others which is a challenge for optimizing their delivery in cities. A global meta-analysis of urban ecosystem service assessments revealed that benefits to air quality, carbon storage, local climate and wildlife were the most frequently evaluated, whilst others were rarely considered (Figure 1b). The spiritual benefits were evaluated in only 2% of cases, biological pest control in 1% of cases and tourism in just 0.2% of cases (Haase et al., 2014). Furthermore, ecosystem services are not independent; there are synergies and trade-offs between services as well as uncertainties in their measurement (Hou, Burkhard, & Müller, 2013). The net effect of some management interventions can be negative if there are unintended declines in other ecosystem services. This disparity and complexity may explain why some ecosystem services are more regularly included in urban ecosystem management plans.

In this article, we argue that greenspaces in cities should be a key focus of attention in improving human–nature interactions, because this is where most people live (Sanderson, Walston, & Robinson, 2015) and cities have a disproportionate impact on the environment beyond the city limits and at local to global scales (Grimm et al., 2008; Grimm, Grove, Pickett, & Redman, 2000; Seto, Guneralp, & Hutyra, 2012; Seto, Reenberg, et al., 2012). Ensuring these urban greenspaces endure is in large part dependent on healthy trees and in turn their belowground (e.g., mycorrhizas) and aboveground (e.g., pollinators) interactions. Fungi are overlooked in some assessments of biodiversity decline (e.g., in Díaz et al., 2018, 2019; Field, Daniel, Johnson, & Helgason, 2020) so here we highlight their essential function for trees and importance for urban ecosystems. Pollinators, on the other hand, have captured the public imagination and their ecological function is well understood by non-experts. Public enthusiasm for saving bees, however, is almost entirely focused on honey bees with an unsustainable proliferation of urban beekeeping that may actually do more harm to bee conservation than good (Ropars, Dajoz, Fontaine, Muratet, & Geslin, 2019). Furthermore, bee conservation has overlooked the critical contributions of trees through provision of pollen, nectar, and nesting sites (Baldock et al., 2015, 2019). Advocacy on biodiversity in urban ecosystems and more widely should seek to communicate in language and methods suitable to a diverse target audience but should avoid over-simplified messaging.

Here we consider the role of trees in urban ecosystems to optimize delivery of services, and human well-being. We assess how green spaces in cities support biodiversity and provide opportunities for people to interact with and learn about nature and inspire behavioral changes that reduce or eliminate negative impacts on biodiversity. We highlight the importance of tree diversity in maintenance and renewal of urban ecosystems and the importance of below- and aboveground interactions identifying a) where more research is needed; b) where additional benefits could be sought; and c) highlight the multiple benefits of urban ecosystems.

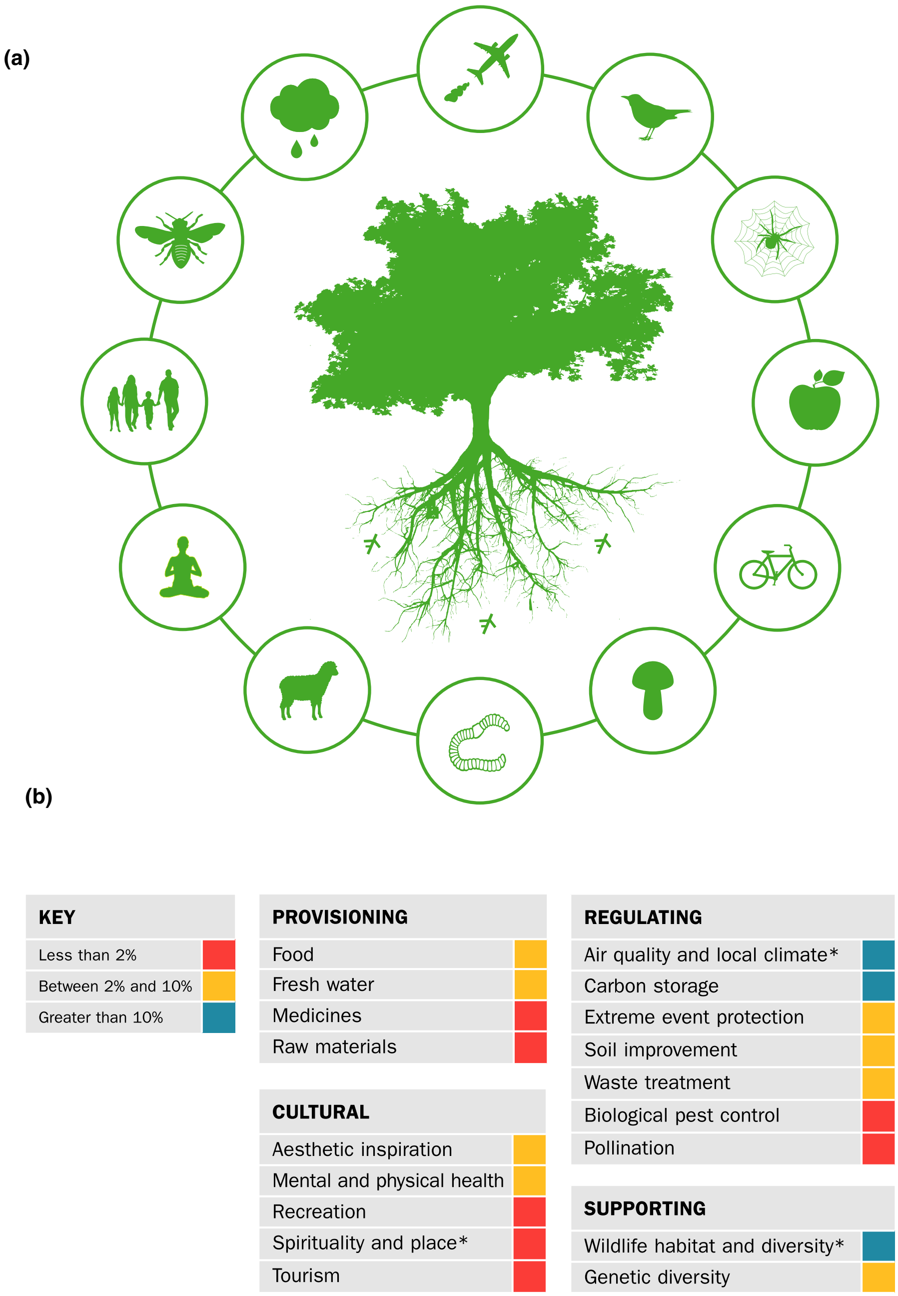

FIGURE 1 Trees and fungi in towns and cities provide important ecosystem services and help support biodiversity. (a) An illustration of some of the ecosystem services delivered by plants and fungi (represented by mycorrhizal "root" fungi) in urban ecosystems; and (b) the proportion of published urban ecosystem service assessments which have evaluated the delivery of the stated service. Data adapted from Haase et al. (2014). Headings adapted from TEEB (2010). *Separate headings in TEEB (2010), but combined in Haase et al. (2014)

2 | FUTURE CHALLENGES OF URBAN TREES

2.1 | Diversity underpins the ecosystem services provided by trees

Trees provide structure, resilience and sustainability in cities (Morgenroth et al., 2016; Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van der Bosch, 2017) and numerous ecosystem services (Figure 1a) which are critical to sustainable urban development and human well-being (Akbari, Pomerantz, & Taha, 2001; Costanza et al., 1997; Deak Sjöman, 2016; Gill, Handley, Ennos, & Pauleit, 2007; Grahn & Stigsdötter, 2003; Morgenroth et al., 2016; Tyrväinen, Mäkinen, & Schipperijn, 2005; Xiao & McPherson, 2002). Larger and healthier trees have the capacity to provide more effective ecosystem services (Gómez-Muñoz, Porta-Gándara, & Fernández, 2010; Gratani & Varone, 2006; Vos, Maiheu, Vankerkom, & Janssen, 2013; Xiao & McPherson, 2002) thus, the biotic and abiotic stresses that limit tree growth impact their capacity to deliver them. The use of site adapted trees is therefore crucial, especially in a future global climate where drier and warmer temperatures or heavy rainfall are predicted that will lead to increased tree mortality (Allen et al., 2010; Teskey et al., 2015). Yet, tree species diversity in urban environments is typically low (Cowett & Bassuk, 2014; McPherson, van Doorn, & de Goede, 2016; Raupp, Buckelew-Cumming, & Raupp, 2006; Yang, Zhou, Ke, & Xiao, 2012). For example, in Scandinavia, common lime or linden (*Tilia* × *europaea*) and silver birch (*Betula pendula*) dominate in cities while in Lhasa, China, poplar (*Populus*) and willow (*Salix*) are the most common genera, and cities in USA are FSAEBO dominated by maple (*Acer*) (Cowett & Bassuk, 2014; Sjöman & Östberg, 2019; Yang et al., 2012).

Urban trees are challenged by pests and pathogens potentially causing large-scale losses that will take years to replace and where low species diversity increases risk. These tree loss scenarios intensify concern about biosecurity when shipping plants globally and where a future scenario might promote in-country nursery production to reduce proliferation of pests and diseases. For example, elms (*Ulmus* spp.) were common urban trees in Europe from the late 1960s, until Dutch elm disease (*Ophiostoma novo-ulmi*) decimated the population (Sinclair & Lyon, 2005) and the tree canopy loss is still recovering. Today, the fungus *Ceratocystis platani* is infecting and killing plane trees (*Platanus* spp.) within 3–7 years of infection (Tsopelas, Santini, Wingfield, & Wilhelm de Beer, 2017). Since London plane (*Platanus* × *hispanica*) is very common in European cities (Sæbø et al., 2005) devastating losses of another large urban tree loom with influences on biodiversity, carbon sequestration, and other benefits. Asian and citrus long-horned beetles (*Anoplophora glabripennis* (ALB) and *A. chinensis*) have wide host ranges presenting an even greater potential threat (Sjöman, Östberg, & Nilsson, 2014). Losses from ALB in nine cities in the USA were estimated at 1.2 billion trees, or $669 billion (Nowak, Pasek, Sequeira, Crane, & Mastro, 2001). The most effective mitigation is increased tree diversity, especially with pest- and disease-resistant species (Alvey, 2006; Hooper et al., 2005). Such targeted tree selection can also reduce peaks of allergenic pollen and biogenic volatile organic compounds produced by some trees that have negative impacts on ozone production and can outweigh their value in mitigating pollution (Asam, Hofer, Wolf, Aglas, & Wallner, 2015; Churkina, Grote, Butler, & Lawrence, 2015; Churkina et al., 2017; Willis & Petrokovsky, 2017). Urban tree inventories in the northern hemisphere are dominated by a handful of species from moist, cool forests making them less suitable for warmer and drier cities (e.g., Cowett & Bassuk, 2014; McPherson et al., 2016; Raupp et al., 2006; Sjöman & Östberg, 2019; Yang et al., 2012). Urban trees globally comprise just a handful of genera including *Acer* (maple), *Fraxinus* (ash), *Platanus* (plane), *Ulmus* (elm), *Picea* (pine), *Quercus* (oak), *Gleditsia* (honeylocust), and *Tilia* (lime, basswood, or linden), for example (Figure 2). To create resilience toward future global challenges such as changing climates or diseases, higher diversity and tree tolerance for site conditions such as flooding, or drought are critical.

2.2 | Which trees will we use in cities in the future?

Long-term sustainable urban tree populations must comprise large, high-quality and healthy trees that can withstand shocks and challenges such as pest and disease outbreaks, climate change and tolerance of urban growing conditions, as well as maintaining the capacity to deliver a wide range of ecosystem services. This demands increased diversity of trees with resilience to local climate and growing conditions (Sjöman, Hirons, & Bassuk, 2018). Selection of site-adapted species and high genera/species diversity is challenging and may require the inclusion of exotic species. For example, in Scandinavia, urban green infrastructure based on native trees is not feasible due to limited native woody flora, where the majority of the native species are challenged by numerous serious pests and diseases and have limited capacity to grow well in inner-city environments (Sjöman, Hirons, & Bassuk, 2015). Regions with a large native species pool exist where climatic or environmental factors permit higher native tree species diversity on urban sites, for example, Central China (Ying & Boufford, 1998), and Brazil (Moro & Castro,

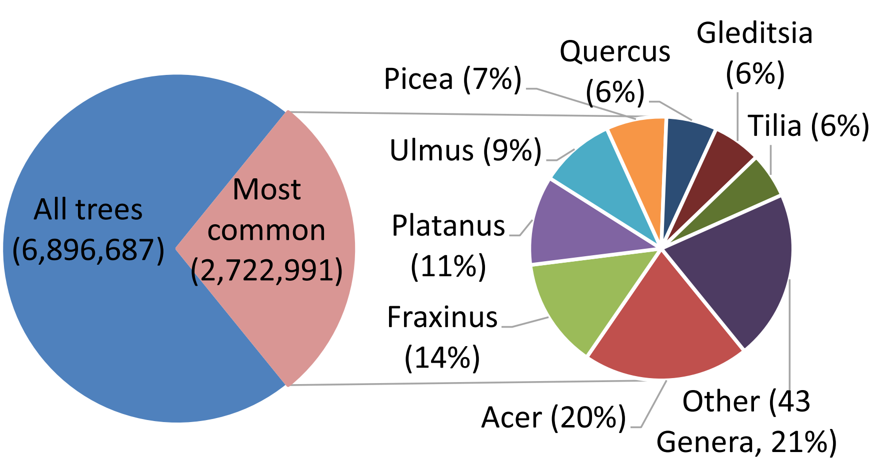

FIGURE 2 Data from OpenTrees (2020) showing the genus of the trees most frequent in cities worldwide. The OpenTrees dataset includes data from 6,896,687 trees in 67 locations around the world. Of these the 10 most frequent species per location ("Most common") account for over 2.7 million trees, of which eight genera; *Acer* (maple), *Fraxinus* (ash), *Platanus* (plane), *Ulmus* (elm), *Picea* (pine), *Quercus* (oak), *Gleditsia* (honeylocust) and *Tilia* (lime, basswood or linden) make up almost 80%

2015). Evidence about the use of non-native trees in urban environments—which ecosystem services they deliver, their capacity to grow in future urban environments/scenarios, and which species or genotypes pose an invasive threat—are required. Use of less traditional city tree species will become increasingly important, therefore tree collections such as arboreta and botanical gardens will have a central role in the development of this knowledge. The three main challenges for research to creating sustainable urban environments and human health are summarized in Box 1.

BOX 1 Challenges for the future in selection of urban trees

The three main challenges for research to creating sustainable urban environments and human health Increase our knowledge about different tree species and suitability of different ecotypes for different urban sites and resilience to future change. Increase our knowledge about different species and ecotypes capacity for delivering ecosystem services and how to use them in order to get the most out of them.Develop knowledge from 1 and 2, but towards rare and untraditional tree species that do not face serious threats of pests and diseases.

2.3 | Quality rather than quantity is the priority

Quality is the priority for urban trees, but quantity drives current policy. Shanghai, Los Angeles, New York, and Sacramento have established planting goals of 1–5 million trees (Shanghai 1.2 Million Tree Planting Project, 2020; Young, 2011) while London has committed to increasing tree canopy cover by 10 percent by 2050 (Transportxtra, 2020). However, provenance matching to site, pest or pathogen vulnerability, and natural pest regulation are critical to ensure development to mature trees and maximize ecosystem service delivery; increasing tree numbers is no guarantee to enhancing the services they provide. Capacity for carbon sequestration or storm water management is dependent on species (e.g., Nowak & Crane, 2002; Xiao & McPherson, 2002) and their mycorrhizal associations (see below) while other species may create disbenefits for example, from casting cold shade during wintertime (Deak Sjöman, Hirons, & Sjöman, 2015) which means selection by site and function specificity is paramount.

Furthermore, tree suppliers must have detailed and qualitative knowledge of the plant material in stock considering for example, that tolerance of warmer and drier climate varies among ecotypes within a species—especially for those with large natural distribution where significant variation occurs. Maples (*Acer* spp.), American ash (*Fraxinus americana*) and northern red oak (*Quercus rubra*), for example, differ across environmental gradients relating to habitat type and precipitation (Alder, Sperry, & Pockman, 1996; Bauerle, Whitlow, Setter, Bauerle, & Vermeylen, 2003; Kubiske & Abrams, 1992; Marchin, Sage, & Ward, 2008; Schuldt et al., 2016; Sjöman et al., 2015) and diversity in these traits is key to ensure longevity in urban tree planting and replacement schemes.

The ideal trees for resilient urban landscapes require optimal genetic architecture but this may not yet be present in existing collections and cultivars. Botanical exploration to date has been driven by interest in scientifically identifying new species or horticultural appeal (Kilpatrick, 2014; Lancaster, 2008; Musgrave, Gardner, & Musgrave, 1998). But botanic gardens still have significant influence in the future selection of urban trees (Cavender & Donnelly, 2019). Evidence-based selection of key traits such as drought tolerance are required to build resilience into urban ecosystems, and this needs to be integrated with horticultural and scientific interests in future botanical exploration. We need to study and identify the diversity of species and their benefits to humanity under changing climate or land-use change and species eradication (Antonelli, Smith, & Simmonds, 2019).

3 | MYCORRHIZAL FUNGI IN THE CITY

3.1 | How do mycorrhizal fungi contribute to nature in urban landscapes?

Ninety percent of known terrestrial plant species engage in symbiotic interactions with fungi via their roots (Brundrett & Tedersoo, 2018) forming different mycorrhizas (meaning "fungus-roots"). Even rootless non-vascular plants can form mycorrhiza-like symbioses (Rimington, Duckett, Field, Bidartondo, & Pressel, 2020). Plants invest up to 20% of their carbon to support fungi in exchange for up to 80% of their nitrogen and 100% of their phosphorus requirement (Smith & Read, 2008). Globally, the most abundant mycorrhizas are arbuscular mycorrhizas (AM), ectomycorrhizas (EM), ericoid and orchid mycorrhizas. Non-mycorrhizal plants are typically weedy herbs (e.g., *Brassicaceae*) or habitat specialists (e.g., Proteaceae). Arbuscular mycorrhizal plants (e.g., London plane—*Platanus x hispanica*, sycamore—*Acer pseudoplatanus*, holly—*Ilex aquifolium*, grass—*Poaceae*) and ectomycorrhizal plants (e.g., oak—*Quercus* spp., spruce—*Picea* spp., lime—*Tilia* spp., birch—*Betula* spp., pine—*Pinus* spp, hazel—*Corylus* spp.) are common in urban areas. Mycorrhizal fungi occur naturally in soils, increasing the volume of explored soil and accessing smaller soil pores far beyond where roots and root hairs can reach (Johnson & Gehring, 2007) leading to increased plant biomass, productivity, and defenses against pests and diseases (Gianinazzi et al., 2010; Rewald, Holzer, & Göransson, 2015). Moreover, many mycorrhizal fungi are host generalists and able to interconnect the roots of different plants, creating belowground networks (van der Heijden & Horton, 2009; Molina & Horton, 2015; Simard et al., 2012) that control seedling establishment and regulate nutrient flow and competition (Tedersoo, Bahram, & Zobel, 2020).

3.2 | The contribution of mycorrhizal fungi to urban ecosystem services

Fungi play multiple roles in urban landscapes providing a wide range of ecosystem services (reviewed in Newbound, Mccarthy, & Lebel, 2018). They are food for many organisms (Bertolino, Vizzini, Wauters, & Tosi, 2004; Lilleskov & Bruns, 2005) including humans (provisioning services), they hold educational, inspirational, and aesthetic value (cultural services) and are involved in supporting services such as soil formation, primary production, nutrient, water and carbon cycling (Smith & Read, 2008). Globally, mycorrhizal fungi drive ecosystem processes (as defined by Potschin-Young et al. (2018)) such as carbon sequestration, mineral weathering, and soil structure and aggregation (van der Heijden, Martin, Selosse, & Sanders, 2015; Tedersoo et al., 2020) which are negatively impacted by low mycorrhizal diversity (Bakker et al., 2019). Over time, trees sequester much more carbon belowground via their roots than aboveground. They pump carbon to the mycorrhizal fungi which extend into the soil via their filaments. Mycorrhizal fungi therefore act as carbon sinks, representing up to one-third of the soil microbial biomass (Högberg & Högberg, 2002; Leake et al., 2004). Moreover, ectomycorrhizal fungi compete with decomposers for the limited resources in the soil organic matter suppressing decomposition rates and resulting in greater carbon sequestration in soil (Fernandez & Kennedy, 2016). Mycorrhizal fungi are also involved in soil formation, water uptake, and transport and nutrient cycling (Fernandez & Kennedy, 2016; Johnson & Gehring, 2007), ecosystem processes that are of particular relevance in urban soils, where fertility, water content, and erosion are often key challenges (Bowles, Jackson, Loeher, & Cavagnaro, 2016). Tree roots and mycorrhizal mycelia increase the soil porosity enhancing water retention and reduce erosion by holding the soil in place. Mycorrhizal fungi influence tree growth and survival and they affect soil aggregation through changes in the root architecture, the production of hydrophobins that enhance adherence to soil surfaces, enmeshing and entangling soil particles and forming aggregates through the oxidation of the soil organic matter (Lehmann & Rillig, 2015; Rillig & Mummey, 2006; Smith & Read, 2008; Tagu et al., 2001). All of these have a decelerating effect on water flows preventing floods.

Richness and composition of both EM and AM fungi are strongly influenced by host and environmental factors including both atmospheric pollution and soil eutrophication (Ceulemans et al., 2019; van der Linde et al., 2018). Urban habitats are unique and often harsh environments for plants, due to disturbance, pollution, drought, radiation, heat, and microclimate extremes, but also due to reduced soil mycorrhizal inoculum and colonization. Comparisons across wild, rural, and urban habitats reveal dramatic differences, with the lowest diversity of fungi in urban environments (Bills & Stutz, 2009). In fact, lack of mycorrhizal relationships compromises plant establishment and growth in a variety of urban, agricultural, and industrial landscapes (Vosátka, Albrechtová, & Patten, 2008). Moreover, non-native plants in urban landscapes can harbor non-native fungi that may replace native species, causing imbalances in urban ecosystems (Lothamer, Brown, Mattox, & Jumpponen, 2014; Nuñez & Dickie, 2014).

Urban reforestation typically requires intensive management using chemicals and fertilizers (Newbound et al., 2010; Pataki et al., 2011). As a sustainable alternative to avoid and/or reduce these, the inoculation of soils and plants with mycorrhizal fungi could enhance plant survival, growth, stress tolerance, and promote soil restoration (Chaudhary, Sandall, & Lazarski, 2019; Fini et al., 2011; John, Kernaghan, & Lundholm, 2016; Pavao-Zuckerman, 2008; Rewald et al., 2015; Stabler, Martin, & Stutz, 2001; Szabó, Böll, & Erös-Honti, 2014). Unfortunately, so far, the application of mycorrhizal fungal inoculum has not always led to significant differences in tree growth or establishment (Ferrini & Nicese, 2002; Gilman, 2001). Therefore, the application of mycorrhizal fungi to be able to support long-term establishment of urban plants, a careful selection of plant species, and appropriate management will be required in the future for the establishment of urban ecosystems (Bowles et al., 2016; Chaudhary et al., 2019; Szabó et al., 2014).

Mycorrhizal fungi therefore provide not only recreational, human health, and economic benefits in urban greenspaces, but also environmental benefits by decreasing the need for fertilizers and pesticides and intercepting nutrients, thus reducing nutrient leaching into groundwater and waterways and the risk of eutrophication (van der Heijden et al., 2015; Tedersoo & Bahram, 2019).

4 | URBAN TREES AND BEES

4.1 | The value of bees in cities

While trees form mutualistic relationships with mycorrhizas below ground, above ground many tree species depend on animal pollination, including urban trees (Hausmann et al., 2016). Pollinators, in turn, collect pollen or nectar as food. Arguably the most important group of pollinators globally are bees (Potts et al., 2016) with around 20,000 species worldwide (Ascher & Pickering, 2020). Most are solitary, ground, or cavity-nesting species. Even though urbanization threatens global biodiversity (Cardoso & Gonçalves, 2018; Hall et al., 2017; Seto, Guneralp, et al., 2012), many bee species thrive in cities with significant green spaces (Beninde, Veith, & Hochkirch, 2015), with urban centers often harboring a diverse and abundant bee fauna (Baldock et al., 2015, 2019; Geslin, Le Féon, Kuhlmann, Vaissière, & Dajoz, 2015; Matteson, Ascher, & Langellotto, 2008; Mazzeo & Torretta, 2015; Saure, 1996; Threlfall et al., 2015). Some cities may even support more bee individuals and species than intensively farmed countryside (Hall et al., 2017; Sirohi, Jackson, Edwards, & Ollerton, 2015; Theodorou et al., 2016, 2020; Wenzel, Grass, Belavadi, & Tscharntke, 2020).

Bees provide a range of ecosystem services in cities. Beyond the production of apicultural products like honey, bees pollinate a range of crops in cities (e.g., apples, strawberries, tomatoes, beans) that supplement the diets of city dwellers and increase

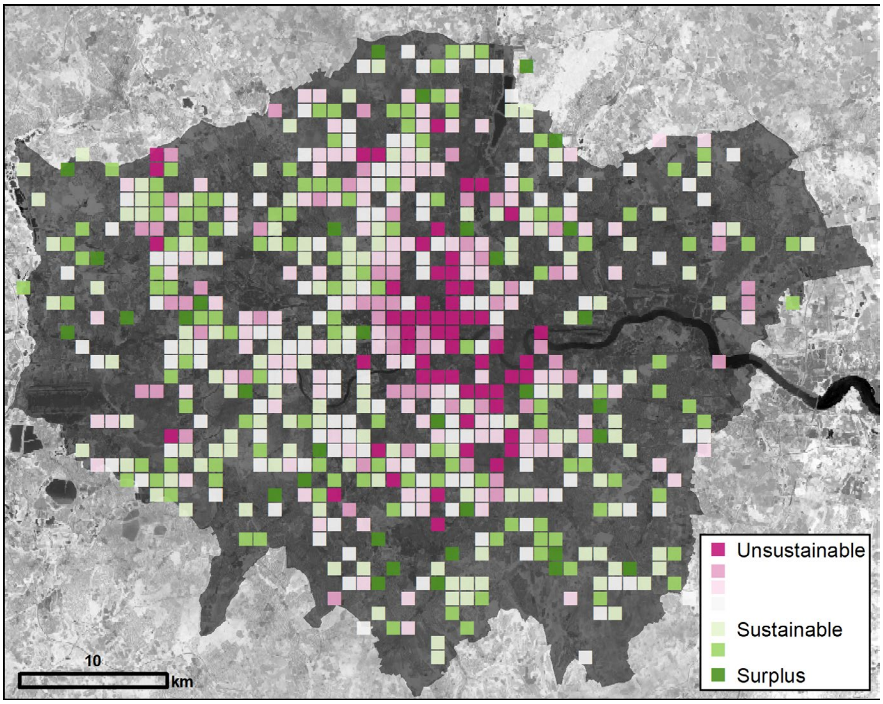

FIGURE 3 Forage (greenspace) and honey bee colony distribution in London showing the available greenspace within 1 km grids for each colony. London's greenspace is derived from June 2018 Landsat imagery and the bee colony density for 2018 from colonies registered on Beebase APHA (2020). Using figures from Alton and Ratnieks (2016b), we estimated 13.28 hectares (0.13 km^2) of London greenspace is required per colony or 7.5 colonies per km^2. This concurs with the highest densities of feral and domestic honey bee colonies (Ratnieks et al., 1991; Requier et al., 2019). Based on this estimation the map uses a divergent palette where green to white is 1–0.13 km^2 of forage per colony (i.e., sustainable to surplus) and white to purple <0.13 km^2 where it is not sustainable for the numbers of bee colonies let alone other competing bee species

food security (Lin, Philpott, & Jha, 2015; Lowenstein, Matteson, & Minor, 2015). Urban landscapes with high bee diversity and abundance may also benefit pollination services in surrounding agricultural landscapes, by acting as refugia and a source of pollinators (Hall et al., 2017; Senapathi et al., 2015). Ensuring healthy urban bee populations may underpin regulating ecosystem services where the plants providing clean air or flood protection depend on pollinators (see discussion in Klein, Boreux, Fornoff, Mupepele, & Pufal, 2018). Bees furthermore have a positive public profile (Sumner, Law, & Cini, 2018) enabling people in cities to connect with nature (Klein et al., 2018).

4.2 | To bee-keep or not to bee-keep

Bee conservation for landowners, stakeholders, and mass media is often focused on the western honey bee (*Apis mellifera*) (Smith & Saunders, 2016). While honey bees make a significant contribution to food production, wild bee species are also critical pollinators (Garibaldi et al., 2014) and often more important than honey bees (Garibaldi et al., 2013). So, while there is a willingness to respond to pollinator declines (Hallmann et al., 2017; Potts et al., 2016; Powney et al., 2019; Wagner, 2020), the outcome has often simply been honey bee hive installation in parks, or on city rooftops (Alton & Ratnieks, 2016a; Colla & MacIvor, 2017; Lorenz & Stark, 2015). Many urban beekeepers see these activities as environmentally important and reducing deficits of pollinators (Alton & Ratnieks, 2016a). However, the number of urban hives has increased dramatically in the last two decades, with potential negative outcomes for wild species. In London, for example, the density of honey bee colonies exceeds 10 hives/km^2 (Alton & Ratnieks, 2016b; with locally more than 30 colonies/km^2)—more than twice the European mean (4.2 hives/km^2) and nearly eight times the UK density (1.3 hives/km^2 - Chauzat et al., 2013).

Besides the potential health risks for humans from higher numbers of bees in cities (e.g., bee venom allergies, Mach & Potter, 2018), our analyses indicate that current bee-hive numbers in London are inadequately supported by available forage in many locations (Figure 3). Alton and Ratnieks (2016b) estimated that 0.83 hectares of lavender are needed for one colony, not taking into account sessional flowering (i.e., a whole season is needed) and that London's green space is not covered in Lavender. We conservatively estimated that x4 the area of lavender would be needed for flowering session (Alton and Ratnieks (2016b) suggest x10) and that less than 1/4 of London's green space was equivalent to lavender. Thus, we estimate that 13.28 hectares (0.13 km^2) of London greenspace is required per colony or 7.5 colonies per km^2. This concurs with the highest densities of feral and domestic honey bee colonies (Ratnieks, Piery, & Cuadriello, 1991; Requier et al., 2019). Based on this estimation the map in Figure 3 shows that beekeeping based on current data is unsustainable in most locations in

London. This is a serious problem for bee conservation because honey bees can outcompete wild bees by monopolizing floral resources (Geslin et al., 2017; Henry & Rodet, 2018; Herrera, 2020; Mallinger, Gaines-Day, & Gratton, 2017; Ropars et al., 2019, 2020; Torné-Noguera, Rodrigo, Osorio, & Bosch, 2016). Wild pollinator populations may also be weakened by diseases spilling over from honey bees (Alger, Alexander Burnham, Boncristiani, & Brody, 2019; Fürst, McMahon, Osborne, Paxton, & Brown, 2014; Graystock, Blane, McFrederick, Goulson, & Hughes, 2016; Singh et al., 2010).

Messaging about "saving bees" should clarify the importance of wild species and beekeeping should be regulated to minimize environmental harm (e.g., see Henry & Rodet, 2020). Urban planning should support bee diversity, and not just promote one highly competitive species (Stevenson, 2019). Practices that support wild bees are easily established: policies need to be implemented that increase floral resources, nesting sites, and reduce chemical pollutants to fulfill the potential of cities as refuges for pollinators. Allotments, urban wastelands, and gardens offer nesting and flowering resources and harbor diverse pollinator populations (Baldock et al., 2019; Lanner et al., 2020) while Britain's private gardens provide diverse flora and cover a wider area than all of its national nature reserves put together (Wildlife Trust, 2020), offering prime opportunities to support bees (Baldock et al., 2015, 2019). Trees can play an integral role in this food provision for bees.

4.3 | The role of trees in supporting urban bees

Trees provide food and nesting resources for urban bee populations. The high floral density in tree crowns results in trees often producing significantly more nectar and pollen per unit area of land than herbaceous plants (Bentrup, Hopwood, Adamson, & Vaughan, 2019; Donkersley, 2019), and trees are especially important food sources when few herbaceous plants are flowering, as in spring and late summer (Koch & Stevenson, 2017; Sponsler, Shump, Richardson, & Grozinger, 2020; Wood, Kaplan, & Szendrei, 2018), or the tropical dry season (Aleixo, de Faria, Groppo, & do Nascimento Castro, & da Silva, 2014). Pollen and nectar from urban trees also have good nutritional quality for bees (Somme et al., 2016). Sugar-rich honeydew produced by sap-sucking insects on trees is also collected by some bees (Koch, Corcoran, & Jonker, 2011; Requier & Leonhardt, 2020). Tree cavities are used as nest sites by social bee colonies, including some honey bees, stingless bees, and bumblebees (Aidar, Santos, Bartelli, Martins, & Nogueira-Ferreira, 2013; Bentrup et al., 2019; Hill & Webster, 1995). Many solitary bees, especially in the Megachilidae and Xylocopinae, also nest in dead wood (Potts et al., 2005; Requier & Leonhardt, 2020). Tree resins, leaves, and trichomes are additionally important materials for nest construction for some bees (Krombein, 1967; MacIvor, 2016; Requier & Leonhardt, 2020). Shade and cooler microclimates provided by trees can protect bees against heat stress (Bentrup et al., 2019), although excessive shading in urban sites is detrimental for thermophilic species (Matteson & Langellotto, 2010).

Both native and non-native tree species can, in principle, support urban bees well (Mach & Potter, 2018; Wenzel et al., 2020). Importantly, the value of trees for urban bees has to be considered within the context of the regional bee fauna. For example, in the German bee fauna, 137 (32%) of the 428 pollen-collecting (non-parasitic) species are oligolectic (i.e., collect pollen from one family) (Westrich, 2018). However, out of these oligolectic bees, over 90% are restricted to pollen of herbaceous plants, and less than 10% collect pollen of woody plants, mostly from willows (*Salix* spp.) (Westrich, 2018). In this Central European context, urban trees, including non-native species like horse chestnut (*Aesculus hippocastanum*) and black locust (*Robinia pseudoacacia*), can be valuable for generalist bees (Hausmann et al., 2016), but trees alone will not support high bee diversity. Herbaceous plant diversity also needs to be promoted, especially for oligolectic species, for example in urban grasslands (Fischer, Eichfeld, Kowarik, & Buchholz, 2016), wasteland/brownfield sites (Twerd & Banaszak-Cibicka, 2019), and gardens and allotments (Baldock, 2020; Baldock et al., 2019). By contrast, many Australian native bee species, particularly within the Colletidae (the most diverse Australian bee family), are pollen specialists of endemic trees and shrubs in the Myrtaceae and Proteaceae (Houston, 2018) and will only thrive in urban settings if these native woody plants are present (Threlfall et al., 2015). Planting non-native ornamental trees in this scenario mostly favors non-native honey bees (Threlfall et al., 2015). Cities in the Neotropics present yet another case. The dominant bee taxa in the tropics, including honey bees (*Apis* spp.), stingless bees (Meliponini), orchid bees (Euglossini), leafcutter bees (*Megachile* spp.) and carpenter bees (*Xylocopa* spp.), rely heavily on trees both as nesting and food resources (Aleixo et al., 2014; Frankie et al., 2013; López-Uribe, Oi, & Del Lama, 2008; Nemésio, Santos, & Vasconcelos, 2015; Roubik, 1992), but this bee fauna is dominated by generalist foragers, with a low single digit percentage of oligolectic bees (Danforth, Minckley, & Neff, 2019; Michener, 1979). A broad range of both native and non-native trees, shrubs and herbaceous plants were accordingly well visited by urban bees in Brazil (Aleixo et al., 2014) and Costa Rica (Frankie et al., 2013), but generally tropical and low-income regions remain understudied for urban pollinators (Wenzel et al., 2020).

An abundance of flowering trees throughout the season may offer a good avenue to reduce competition between honey bees and other bee species in cities with problematically high honey bee densities (see 4.2). As flowering trees are highly attractive to honey bees (Donkersley, 2019; Hill & Webster, 1995; Sponsler et al., 2020), their increased availability could reduce honey bee densities on other flowering plants that are essential to more specialized wild bees, facilitating co-existence of beekeepers and wild bee diversity. If honey bee densities could thus be decreased on forage plants of wild bees, this may also reduce disease transmission of viruses on flowers between bees, which is density dependent (Bailes et al., 2020; Koch, Brown, & Stevenson, 2017).

Regrettably, the benefits provided by different tree species for bees are often not considered when assessing ecosystem services of urban trees (e.g., see Willis & Petrokofsky, 2017). Databases used by urban planners either lack any data on tree-pollinator interactions (see database “i-Tree Eco” (USDA Forest Service, 2016, https://www.itreetools.org/tools/i-tree-eco), or only list whether or not a tree species is a "honey" plant (i.e., provides nectar) for honey bees, not assessing benefits to other pollinator species more broadly (see database “Citree” (Vogt et al., 2017)). We stress that more detailed research and dissemination of the value of different urban tree species for bees is needed, so that it can be included in urban planning decisions.

5 | URBAN ECOSYSTEMS IN THE GLOBAL BIODIVERSITY CRISIS AND IN EDUCATION AND ENGAGEMENT

5.1 | The benefits of plants in urban ecosystems for water purification, pollution, and air quality

Trees and other plants provide various ecosystem services important to urban landscapes including water purification, flood prevention, and improved air quality by disrupting the movement and intercepting, trapping, and altering the deposition of pollutants (Ugolini, Tognetti, Raschi, & Bacci, 2013; Figure 1). However, wind helps to disperse urban pollution, therefore the wrong tree in the wrong place could impede this process leading to higher local pollution levels. Plants also reduce urban temperatures via transpiration and shading (Gillner, Vogt, Tharang, Dettmann, & Roloff, 2015). Since the volatilization of many pollutants is influenced by temperature (e.g., organic pollutants), the cooling effect of trees may reduce the negative impacts of Biogenic Volatile Organic Compounds (Willis & Petrokofsky, 2017). A lowering of temperatures on hot days in cities reduces the need to cool buildings, giving additional economic and environmental benefits (McPherson & Simpson, 2003). The inclusion of greenspace in cities also encourages more physical activity (Braubach et al., 2017) which could lead to reduced use of polluting vehicles and lower levels of pollutants.

Roadside verges are sites of runoff from nitrogenous or heavy metal pollutants, but trees and other plants can assimilate them and reduce impacts (Zhu, Christie, & Laidlaw, 2001). Nitrogen is an important pollutant of stormwater in urban areas causing eutrophication and algal blooms but plant-based biofiltration systems can intercept nitrogen before it pollutes waterways (Hatt, Fletcher, & Deletic, 2008). Additionally, in urban environments, levels of nutrient inputs (fertilizers on lawn) can be excessive (Sharma, Herne, Byrne, & Kin, 1996), it is important that plants in urban ecosystems are managed carefully to avoid or reduce pollution (e.g., excess fertilizer inputs).

5.2 | Capitalizing on cultural value of trees, fungi, and bees to engage the urban public

Plants and fungi have underpinned the material culture of humanity providing food, shelter, tools, and medicine, but also serving aesthetic and symbolic values and satisfying secular and also spiritual needs (Balick & Cox, 1997; Kew, 2016; Schultes, Hofmann, & Rätsch, 1992; Yotapakdee et al., 2019). Urban forests can contribute to the creation of a local identity, enhance sense of place, increase aesthetic appreciation, inspire artistic expression, foster tourism, and mitigate stress (Diaz et al., 2018; FAO, 2018; Rathmann et al., 2020). For the public, urban forests can positively impact mood and psychological well-being (FAO, 2018;; Hobhouse, 2004; Rathmann et al., 2020), and forest bathing (Shinrin Yoku) has been reported to afford medical health benefits (Li, 2010) while urban trees as oxygen and shade suppliers are also widely appreciated (Camacho-Cervantes, Schondube, Castillo, & MacGregor-Fors, 2014). However, tree retention and planting is not universally welcomed in urban areas by all stakeholders who often relate it to safety issues (i.e., accidents, infrastructure damage), health issues (i.e., allergies), economic and mobility issues, and possible inadequate long-term management (Camacho-Cervantes et al., 2014; Carmichael & McDonough, 2018; Lyytimäki, Petersen, Normander, & Bezák, 2008). Similarly, fungi (especially macrofungi) and bees are not universally welcomed by humans (Boa, 2004; Gerdes, Uhl, & Alpers, 2009).

Urbanization and loss of natural habitats have resulted in less human interaction with nature. Nevertheless, wild products continue to be consumed, and present an important opportunity to engage with and appreciate biodiversity (Poe, McLain, Emery, & Hurley, 2013; Reyes-García et al., 2015). Different public needs are placed on cities' urban trees in different regions of the world, for example, in the USA there are movements to make urban forests serve as agroecological landscapes where people can gather, and practice food (including livestock) production (McLain, Poe, Hurley, Lecompte-Mastenbrook, & Emery, 2012). Wild food foraging is increasingly popular and while there are purported negative consequences for diversity in urban settings, the evidence suggests this is limited (Egli, Peter, Buser, Stahel, & Ayer, 2006).

Contemporary interest in wild goods is growing and provides an opportunity to engage urban citizens in nature. Bioblitz and other citizen science activities in urban settings are an excellent way to increase the knowledge of trees, fungi, and bees among members of the public. These recording activities also provide useful information on fungal and bee distributions (Baker, Duncan, Gostomski, Horner, & Manski, 2014; Falk et al., 2019; Newbound et al., 2010) and tree conditions (Johnson et al., 2018) in urban areas.

Opportunities to interact with nature across seasons and at all times of the day and a range of human–nature relationships must be encouraged (Barnes et al., 2019; Fabjanski & Brymer, 2017; Richardson & McEwen, 2019). Exercising outdoors and in sight of nature has additional benefits for our relationship with the natural world by reducing anxiety (Bratman et al., 2015; Hyvönen et al., 2018; Lawton et al., 2017; Niedermeier, Hartl, & Kopp, 2017; Wooller, Barton, Gladwell, & Micklewright, 2016). Even virtual reality interactions can have a positive impact for those with limited access to nature (Calogiuri et al., 2018; Nguyen & Brymer, 2018).

The challenge for urban and peri-urban ecosystems today is to maintain the multiple services benefits and needs of different people from recreation to foraging and even therapy (Li, 2010; Stara, Tsiakiris, & Wong, 2015; Takayama et al., 2014; Ulrich et al., 1991). Such interactions could help to raise public awareness about nature and to rethink and change behaviors about how we value nature and biodiversity (Alcock et al., 2020; Diaz et al., 2018). Urban trees, fungi, and bees are an untapped educational resource for raising public awareness of the importance of biodiversity for ecosystem service provision in both urban and rural habitats.

6 | CONCLUSIONS AND RECOMMENDATIONS

Urban ecosystems offer opportunities for positive public engagement with nature and provide a platform to optimize human–nature interactions as the health of both are inextricably linked (Diaz et al., 2019). Daily interactions with nature are important and cities must provide greenspace close to homes and work, so that they are encountered easily and frequently. The trees and other plants, on which these urban ecosystems depend, must be selected carefully and considerately, alongside their mutualists including mycorrhizal fungi and invertebrates, to maximize resilience to current and future constraints. People can be informed about the value of diverse fungal communities and their threats in urban ecosystems and a targeted management including this functionally important group could be developed. Intraspecific tree diversity should also be prioritized especially where urban settings present more challenging conditions such as a warmer and periodically drier climate.

While we highlight the importance of good messaging which does not over simplify the challenges or solutions, a stronger focus on management issues is required in future assessments of ecosystems in urban settings looking at how challenges are being addressed and why, but also how approaches differ around the world with a focus on their successes and failures to draw lessons and improve ecosystem management. In particular, ecosystem service assessments must measure as many ecosystem services as possible over multiple timeframes and at different scales so that we can understand the impacts of urban ecosystems and of management interventions on the full spectrum of the services provided. Consideration of uncertainties, synergies, and trade-offs is essential in ecosystem management plans to optimize the delivery of ecosystem services and to avoid unwanted negative impacts on non-target ecosystem services.

Habitats that support a diversity of wildlife that is accessible and supplemented with information that fosters understanding and significance for human well-being must be established. Variation across species groups, both native and non-native, can create a bond between people and natural places, enhancing their appreciation of nature (Schebella, Weber, Schultz, & Weinstein, 2020). This includes honey bees, a key species for engaging the public with nature and ecosystem concepts, but as with all manipulation of nature this needs to be done with care for the consequences. Messaging needs to be clear and we must share the complexity of biodiversity rather than allowing a single issue to dominate. Saving bees is laudable, but if this leads to excessive interest in apiculture in cities and honey bees outcompete wild bee species, then rather than saving bees we may be depleting bee diversity (Geldman & González-Varo, 2018). Similar oversimplified public messages could lead to over enthusiasm for tree planting without considering which species and where.

We must provide environments that in themselves are compelling and encourage time spent in nature. Exercising outdoors and in sight of nature has additional benefits of the relationship with the natural world and reducing anxiety (Hyvönen et al., 2018; Lawton et al., 2017; Niedermeier et al., 2017; Wooller et al., 2016). Even virtual reality interactions can have a positive impact for those with limited access to nature (Calogiuri et al., 2018; Nguyen & Brymer, 2018).

Ultimately the future well-being of the natural world and humanity demands a commitment and an authentic desire to refocus political and practical efforts on effective human–nature relationships. With more than half of the world's population living in towns or cities, urban settings are arguably where the majority of influence can be made. Only through this approach with effective engagement of people and nature will efforts to stop biodiversity loss and reverse declines in species be realized.

ACKNOWLEDGEMENTS

The authors and trustees of the Royal Botanic Gardens, Kew and the Kew Foundation would like to thank the Sfumato Foundation for generously funding the State of the World's Plants and Fungi project. We acknowledge from the Royal Botanic Gardens, Kew, Jeff Eden, and Ines Stuart Davidson for the production of Figure 1. We also thank Animal Plant Health Agency (UK) (885666702) for hive data for London.

AUTHOR CONTRIBUTIONS

P.C.S. developed the overarching review plan and drafted the document summaries, introduction and concluding remarks and edited the whole document. M.B., R.B.-M., T.C., A.C., B.G., H.K., M.L., J.M., R.O., H.S., A.S., K.S., L.S. all drafted sections of text or figures and associated text where relevant to their expertise and all authors edited the final draft.

ORCID

Philip C. Stevenson https://orcid.org/0000-0002-0736-3619
Martin I. Bidartondo https://orcid.org/0000-0003-3172-3036
Robert Blackhall-Miles https://orcid.org/0000-0002-8020-5609
Timothy R. Cavagnaro https://orcid.org/0000-0002-9922-5677
Benoît Geslin https://orcid.org/0000-0002-2464-7998
Hauke Koch https://orcid.org/0000-0002-2694-7775
Mark A. Lee https://orcid.org/0000-0001-8060-2762
Justin Moat https://orcid.org/0000-0002-5513-3615
Richard O'Hanlon https://orcid.org/0000-0002-0595-0246
Henrik Sjöman https://orcid.org/0000-0002-5526-6303
Adriano Sofo https://orcid.org/0000-0003-0305-308X
Kalliopi Stara https://orcid.org/0000-0002-4398-608X
Laura M. Suz https://orcid.org/0000-0003-4742-572X

REFERENCES

Aidar, I. F., Santos, A. O. R., Bartelli, B. F., Martins, G. A., & Nogueira-Ferreira, F. H. (2013). Nesting ecology of stingless bees (Hymenoptera, Meliponina) in urban areas: The importance of afforestation. *Bioscience Journal*, *29*, 1361–1369.

Akbari, H., Pomerantz, M., & Taha, H. (2001). Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas. *Solar Energy*, *70*(3), 295–310. https://doi.org/10.1016/S0038-092X(00)00089-X

Alcock, I., White, M. P., Pahl, S., Duarte-Davidson, R., & Fleming, L. E. (2020). Associations between pro-environmental behaviour and neighbourhood nature, nature visit frequency and nature appreciation: Evidence from a nationally representative survey in England. *Environment International*, *136*, 105441. https://doi.org/10.1016/j.envint.2019.105441

Alder, N., Sperry, J., & Pockman, W. (1996). Root and stem xylem embolism, stomatal conductance, and leaf turgor in *Acer grandidentatum* populations along a soil moisture gradient. *Oecologia*, *105*(3), 293–301. https://doi.org/10.1007/BF00328731

Aleixo, K. P., de Faria, L. B., Groppo, M., do Nascimento Castro, M. M., da Silva, C. I. (2014). Spatiotemporal distribution of floral resources in a Brazilian city: Implications for the maintenance of pollinators, especially bees. *Urban Forestry & Urban Greening*, *13*, 689–696.

Alger, S. A., Alexander Burnham, P., Boncristiani, H. F., & Brody, A. K. (2019). RNA virus spillover from managed honeybees (*Apis mellifera*) to wild bumblebees (*Bombus* spp.). *PLoS One*, *14*, 1–13. https://doi.org/10.1371/journal.pone.0217822

Allan, J. R., Watson, J. E., Di Marco, M., O'Bryan, C. J., Possingham, H. P., Atkinson, S. C., & Venter, O. (2019). Hotspots of human impact on threatened terrestrial vertebrates. *PLoS Biology*, *17*, e3000158. https://doi.org/10.1371/journal.pbio.3000158

Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., … Cobb, N. (2010). A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology & Management*, *259*, 660–684. https://doi.org/10.1016/j.foreco.2009.09.001

Alton, K., & Ratnieks, F. L. W. (2016a). Roof top hives: Practical beekeeping or publicity stunt? *Bee World*, *93*(3), 64–67.

Alton, K., & Ratnieks, F. L. W. (2016b). To Bee or not to Bee. *The Biologist*, *60*(4), 12–15.

Alvey, A. A. (2006). Promoting and preserving biodiversity in the urban forest. *Urban Forestry and Urban Greening*, *5*, 195–201. https://doi.org/10.1016/j.ufug.2006.09.003

Antonelli, A., Smith, R. J., & Simmonds, M. S. J. (2019). Unlocking the properties of plants and fungi for sustainable development. *Nature Plants*, *5*, 1100–1102. https://doi.org/10.1038/s41477-019-0554-1

Asam, C., Hofer, H., Wolf, M., Aglas, L., & Wallner, M. (2015). Tree pollen allergens—An update from a molecular perspective. *Allergy*, *70*(10), 1201–1211. https://doi.org/10.1111/all.12696

Ascher, J. S., & Pickering, J. (2020). *Discover Life bee species guide and world checklist (Hymenoptera: Apoidea: Anthophila)*. http://www.discoverlife.org/mp/20q?guide=Apoidea_species (accessed 05/08/20)

Bailes, E. J., Bagi, J., Coltman, J., Fountain, M. T., Wilfert, L., & Brown, M. J. F. (2020). Host density drives viral, but not trypanosome, transmission in a key pollinator. *Proceedings of the Royal Society B*, *287*, 20191969.

Baker, G. M., Duncan, N., Gostomski, T., Horner, M. A., & Manski, D. (2014). The bioblitz: Good science, good outreach, good fun. *Park Science*, *31*(1), 39–45.

Bakker, M. R., Brunner, I., Ashwood, F., Bjarnadottir, B., Bolger, T., Børja, I., … Erktan, A. (2019). Belowground biodiversity relates positively to ecosystem services of European forests. *Frontiers in Forests and Global Change*, *2*, 6. https://doi.org/10.3389/ffgc.2019.00006

Baldock, K. C. (2020). Opportunities and threats for pollinator conservation in global towns and cities. *Current Opinion in Insect Science*, *38*, 63–71. https://doi.org/10.1016/j.cois.2020.01.006

Baldock, K. C. R., Goddard, M. A., Hicks, D. M., Kunin, E., Mitschunas, N., Osgathorpe, L. M., … Memmott, J. (2015). Where is the UK's pollinator biodiversity? The importance of urban areas for flower-visiting insects. *Proceedings of the Royal Society B Biological Sciences*, *282*, 20142849. https://doi.org/10.1098/rspb.2014.2849

Baldock, K. C. R., Goddard, M. A., Hicks, D. M., Kunin, W. E., Mitschunas, N., Morse, H., … Memmott, J. (2019). A systems approach reveals urban pollinator hotspots and conservation opportunities. *Nature Ecology and Evolution*, *3*, 363–373. https://doi.org/10.1038/s41559-018-0769-y

Balick, M. J., & Cox, P. A. (1997). *Plants, people, and culture: The science of ethnobotany*. New York: Scientific American Library.

Barnes, M. R., Donahue, M. L., Keeler, B. L., Shorb, C. M., Mohtadi, T. Z., & Shelby, L. J. (2019). Characterizing nature and participant experience in studies of nature exposure for positive mental health: An integrative review. *Frontiers in Psychology*, *9*, 2617. https://doi.org/10.3389/fpsyg.2018.02617

Bauerle, W. L., Whitlow, T. H., Setter, T. L., Bauerle, T. L., & Vermeylen, F. M. (2003). Ecophysiology of Acer rubrum seedlings from contrasting hydrologic habitats: Growth, gas exchange, tissue water relations, abscisic acid and carbon isotope discrimination. *Tree Physiology*, *23*, 841–850.

BeeBase (APHA). (2020). Retrieved from: http://www.nationalbeeunit.com.

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*(6), 581–592.

Bentrup, G., Hopwood, J., Adamson, N. L., & Vaughan, M. (2019). Temperate agroforestry systems and insect pollinators: A review. *Forests*, *10*, 981.

Bertolino, S., Vizzini, A., Wauters, L. A., & Tosi, G. (2004). Consumption of hypogeous and epigeous fungi by the red squirrel (*Sciurus vulgaris*) in subalpine conifer forests. *Forest Ecology and Management*, *202*, 227–233. https://doi.org/10.1016/j.foreco.2004.07.024

Bills, R. J., Stutz, J. C. (2009). AMF associated with indigenous and non-indigenous plants at urban and desert sites in Arizona. In C. Azcón-Aguilar (Ed.), *Mycorrhizas - functional processes and ecological impact* (pp. 207–220). Berlin, Heidelberg: Springer-Verlag. https://doi.org/10.1007/978-3-540-87978-7_14

Boa, E. R. (2004). *Wild edible fungi: a global overview of their use and importance to people (No. 17)*. Food & Agriculture Org. http://www.fao.org/3/y5489e/y5489e00.htm#Contents (accessed 05/08/20).

Bowles, T. M., Jackson, L. E., Loeher, M., & Cavagnaro, T. R. (2016). Ecological intensification and arbuscular mycorrhizas: A meta-analysis of tillage and cover crop effects. *Journal of Applied Ecology*, *54*, 1785–1793. https://doi.org/10.1111/1365-2664.12815

Bratman, G. N., Daily, G. C., Levy, B. J., & Gross, J. J. (2015). The benefits of nature experience: Improved affect and cognition. *Landscape and Urban Planning*, *138*, 41–50.

Braubach, M., Egorov, A., Mudu, P., Wolf, T., Ward, T. C., & Martuzzi, M. (2017). Effects of urban green space on environmental health, equity and resilience. In N. Kabisch, H. Korn, J. Stadler, & A. Bonn (Eds.), *Nature-based solutions to climate change adaptation in urban areas*. Springer, Cham: Theory and Practice of Urban Sustainability Transitions.

Brundrett, M. C., & Tedersoo, L. (2018). Evolutionary history of mycorrhizal symbioses and global host plant diversity. *New Phytologist*, *220*(4), 1108–1115. https://doi.org/10.1111/nph.14976

Calogiuri, G., Litleskare, S., Fagerheim, K. A., Rydgren, T. L., Brambilla, E., & Thurston, M. (2018). Experiencing Nature through immersive virtual environments: Environmental perceptions, physical engagement, and affective responses during a simulated nature walk. *Frontiers in Psychology*, *8*. https://doi.org/10.3389/fpsyg.2017.02321

Camacho-Cervantes, M., Schondube, J. E., Castillo, A., & MacGregor-Fors, I. (2014). How do people perceive urban trees? Assessing likes and dislikes in relation to the trees of a city. *Urban Ecosystems*, *17*(3), 761–773. https://doi.org/10.1007/s11252-014-0343-6

Cardoso, M. C., & Gonçalves, R. B. (2018). Reduction by half: The impact on bees of 34 years of urbanization. *Urban Ecosystems*, *21*, 943–949. https://doi.org/10.1007/s11252-018-0773-7

Carmichael, C. E., & McDonough, M. H. (2018). The trouble with trees? Social and political dynamics of street tree-planting efforts in Detroit, Michigan, USA. *Urban Forestry & Urban Greening*, *31*, 221–229. https://doi.org/10.1016/j.ufug.2018.03.009

Cavender, N., & Donnelly, G. (2019). Intersecting urban forestry and botanical gardens to address big challenges for healthier trees, people, and cities. *Plants*, *People*, *Planet*, *1*(4), 315–322. https://doi.org/10.1002/ppp3.38

Ceulemans, T., Van Geel, M., Jacquemyn, H., Boeraeve, M., Plue, J., Saar, L., … Honnay, O. (2019). Arbuscular mycorrhizal fungi in European grasslands under nutrient pollution. *Global Ecology and Biogeography*, *28*, 1796–1805. https://doi.org/10.1111/geb.12994

Chaudhary, V. B., Sandall, E. L., & Lazarski, M. V. (2019). Urban mycorrhizas: Predicting arbuscular mycorrhizal abundance in green roofs. *Fungal Ecology*, *40*, 12–19. https://doi.org/10.1016/j.funeco.2018.03.002

Chauzat, M. P., Cauquil, L., Roy, L., Franco, S., Hendrikx, P., & Ribière-Chabert, M. (2013). Demographics of the European apicultural industry. *PLoS One*, *8*, https://doi.org/10.1371/journal.pone.0079018

Churkina, G., Grote, R., Butler, T. M., & Lawrence, M. (2015). Natural selection? Picking the right trees for urban greening. *Environmental Science & Policy*, *47*, 12–17. https://doi.org/10.1016/j.envsci.2014.10.014

Churkina, G., Kuik, F., Bonn, B., Lauer, A., Grote, R., Tomiak, K., & Butler, T. M. (2017). Effect of VOC emissions from vegetation on air quality in Berlin during a heatwave. *Environmental Science & Technology*, *51*(11), 6120–6130. https://doi.org/10.1021/acs.est.6b06514

Colla, S. R., & MacIvor, J. S. (2017). Questioning public perception, conservation policy, and recovery actions for honeybees in North America. *Conservation Biology*, *31*(5), 1202–1204.

Costanza, R., D'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., … Van Den Belt, M. (1997). The value of the world's ecosystem services and natural capital. *Nature*, *387*, 253–260. https://doi.org/10.1038/387253a0

Cowett, F. D., & Bassuk, N. L. (2014). Statewide assessment of street trees in New York State, USA. *Urban Forestry and Urban Greening*, *13*, 213–220. https://doi.org/10.1016/j.ufug.2014.02.001

Danforth, B. N., Minckley, R. L., & Neff, J. L. (2019). *The solitary bees: Biology*, *evolution*, *conservation*. Princeton, NJ: Princeton University Press.

Deak Sjöman, J. (2016). *The Hidden Landscape – On fine-scale green structure and its role in regulating ecosystem services in the urban environment*. Doctoral Thesis, Swedish University of Agricultural Sciences Alnarp 2016:3.

Deak Sjöman, J., Hirons, A., & Sjöman, H. (2015). Branch area index of solitaire trees – Its use for designing with regulating ecosystem services. *Journal of Environmental Quality*, *45*(1), 175–187.

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., … Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, *359*, 270–272. https://doi.org/10.1126/science.aap8826

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Agard, J., Arneth, A., … Garibaldi, L. A. (2019). Pervasive human-driven decline of life on Earth points to the need for transformative change. *Science*, *366*, 1327. https://doi.org/10.1126/science.aax3100

Donkersley, P. (2019). Trees for bees. *Agriculture*, *Ecosystems & Environment*, *270*, 79–83.

Duffy, J. E., Godwin, C. M., & Cardinale, B. J. (2017). Biodiversity effects in the wild are common and as strong as key drivers of productivity. *Nature*, *549*, 261–264. https://doi.org/10.1038/nature23886

Egli, S., Peter, M., Buser, C., Stahel, W., & Ayer, F. (2006). Mushroom picking does not impair future harvests – Results of a long-term study in Switzerland. *Biological Conservation*, *129*, 271–276. https://doi.org/10.1016/j.biocon.2005.10.042

Fabjanski, M., & Brymer, E. (2017). Enhancing health and wellbeing through immersion in nature: A conceptual perspective combining the stoic and buddhist traditions. *Frontiers in Psychology*, *8*, 1573. https://doi.org/10.3389/fpsyg.2017.01573

Falk, S., Foster, G., Comont, R., Conroy, J., Bostock, H., Salisbury, A., … Smith, B. (2019). Evaluating the ability of citizen scientists to identify bumblebee (*Bombus*) species. *PLoS One*, *14*(6), e0218614. https://doi.org/10.1371/journal.pone.0218614

FAO (2018). *The state of the World's forests 2018 - forest pathways to sustainable development*. Rome: Licence - CC BY-NC-SA 3.0 IGO.

Fernandez, C. W., & Kennedy, P. G. (2016). Revisiting the "Gadgil effect": Do interguild fungal interactions control carbon cycling in forest soils? *New Phytologist*, *209*, 1382–1394. https://doi.org/10.1111/nph.13648

Ferrini, F., & Nicese, F. P. (2002). Response of English Oak (*Quercus robur* L.) trees to biostimulants application in the urban environment. *Journal of Arboriculture*, *28*(2), 70–75.

Field, K. J., Daniel, T., Johnson, D., & Helgason, T. (2020). Mycorrhizas for a changing world: Sustainability, conservation, and society. *Plants*, *People*, *Planet*, *2*(2), 98–103. https://doi.org/10.1002/ppp3.10092

Fini, A., Frangi, P., Amoroso, G., Piatti, R., Faoro, M., Bellasio, C., & Ferrini, F. (2011). Effect of controlled inoculation with specific mycorrhizal fungi from the urban environment on growth and physiology of containerized shade tree species growing under different water regimes. *Mycorrhiza*, *21*, 703–719. https://doi.org/10.1007/s00572-011-0370-6

Fischer, L. K., Eichfeld, J., Kowarik, I., & Buchholz, S. (2016). Disentangling urban habitat and matrix effects on wild bee species. *PeerJ*, *4*, e2729.

Frankie, G. W., Vinson, S. B., Rizzardi, M. A., Griswold, T. L., Coville, R. E., Grayum, M. H., … Pawelek, J. C. (2013). Relationships of bees to host ornamental and weedy flowers in urban Northwest Guanacaste Province, Costa Rica. *Journal of the Kansas Entomological Society*, *86*, 325–351.

Fürst, M. A., McMahon, D. P., Osborne, J. L., Paxton, R. J., & Brown, M. J. F. (2014). Disease associations between honeybees and bumblebees as a threat to wild pollinators. *Nature*, *506*, 364–366. https://doi.org/10.1038/nature12977

Garibaldi, L. A., Carvalheiro, L. G., Leonhardt, S. D., Aizen, M. A., Blaauw, B. R., Isaacs, R., … Morandin, L. (2014). From research to action: Enhancing crop yield through wild pollinators. *Frontiers in Ecology and the Environment*, *12*, 439–447. https://doi.org/10.1890/130330

Garibaldi, L. A., Steffan-Dewenter, I., Winfree, R., Aizen, M. A., Bommarco, R., Cunningham, S. A., … Bartomeus, I. (2013). Wild pollinators enhance fruit set of crops regardless of honey bee abundance. *Science*, *339*, 1230200. https://doi.org/10.1126/science.1230200

Geldmann, J., & González-Varo, J. P. (2018). Conserving honeybees does not help wildlife. *Science*, *359*, 392–393. https://doi.org/10.1126/science.aar2269

Gerdes, A. B., Uhl, G., & Alpers, G. W. (2009). Spiders are special: Fear and disgust evoked by pictures of arthropods. *Evolution and Human Behavior*, *30*, 66–73. https://doi.org/10.1016/j.evolhumbehav.2008.08.005

Geslin, B., Gauzens, B., Baude, M., Dajoz, I., Fontaine, C., Henry, M., … Vereecken, N. J. (2017). Massively Introduced managed species and their consequences for plant-pollinator interactions. *Advances in Ecological Research*, *57*, 147–199. https://doi.org/10.1016/bs.aecr.2016.10.007

Geslin, B., Le Féon, V., Kuhlmann, M., Vaissière, B. E., & Dajoz, I. (2015). The bee fauna of large parks in downtown Paris, France. *Annales*

De La Société Entomologique De France, *51*, 487–493. https://doi.org/10.1080/00379271.2016.1146632
Gianinazzi, S., Gollotte, A., Binet, M.-N., van Tuinen, D., Redecker, D., & Wipf, D. (2010). Agroecology: The key role of arbuscular mycorrhizas in ecosystem services. *Mycorrhiza*, *20*, 519–530. https://doi.org/10.1007/s00572-010-0333-3
Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: The role of the green infrastructure. *Built Environment*, *33*(1), 115–133.
Gillner, S., Vogt, J., Tharang, A., Dettmann, S., & Roloff, A. (2015). Role of street trees in mitigating effects of heat and drought at highly sealed urban sites. *Landscape and Urban Planning*, *143*, 33–42. https://doi.org/10.1016/j.landurbplan.2015.06.005
Gilman, E. F. (2001). Effect of nursery production method, irrigation, and inoculation with mycorrhizae-forming fungi on establishment of *Quercus virginiana*. *Journal of Arboriculture*, *27*, 30–38.
Gómez-Muñoz, V. M., Porta-Gándara, M. A., & Fernández, J. L. (2010). Effect of tree shades in urban planning in hot-arid climatic regions. *Landscape and Urban Planning*, *94*(3–4), 149–157. https://doi.org/10.1016/j.landurbplan.2009.09.002
Grahn, P., & Stigsdötter, A. U. (2003). Landscape planning and stress. *Urban Forestry and Urban Greening*, *2*, 1–18. https://doi.org/10.1078/1618-8667-00019
Gratani, L., & Varone, L. (2006). Carbon sequestration by Quercus ilex L. and Quercus pubescens Willd. and their contribution to decreasing air temperature in Rome. *Urban Ecosystems*, *9*, 27–37. https://doi.org/10.1007/s11252-006-5527-2
Graystock, P., Blane, E. J., McFrederick, Q. S., Goulson, D., & Hughes, W. O. (2016). Do managed bees drive parasite spread and emergence in wild bees? *International Journal for Parasitology: Parasites and Wildlife*, *5*, 64–75. https://doi.org/10.1016/j.ijppaw.2015.10.001
Grimm, N. B., Faeth, S. H., Golubiewski, N. E., Redman, C. L., Wu, J., Bai, X., & Briggs, J. M. (2008). Global change and the ecology of cities. *Science*, *319*(5864), 756–760.
Grimm, N. B., Grove, J. G., Pickett, S. T., & Redman, C. L. (2000). Integrated approaches to long-term studies of urban ecological systems. *BioScience*, *50*(7), 571–584.
Haase, D., Larondelle, N., Andersson, E., Artmann, M., Borgström, S., Breuste, J., … Elmqvist, T. (2014). A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation. *Ambio*, *43*, 413–433. https://doi.org/10.1007/s13280-014-0504-0
Hall, D. M., Camilo, G. R., Tonietto, R. K., Ollerton, J., Ahrné, K., Arduser, M., … Threlfall, C. G. (2017). The city as a refuge for insect pollinators. *Conservation Biology*, *31*, 24–29. https://doi.org/10.1111/cobi.12840
Hallmann, C. A., Sorg, M., Jongejans, E., Siepel, H., Hofland, N., Schwan, H., … De Kroon, H. (2017). More than 75 percent decline over 27 years in total flying insect biomass in protected areas. *PLoS One*, *12*, https://doi.org/10.1371/journal.pone.0185809
Hatt, B. E., Fletcher, T. D., & Deletic, A. (2008). Hydraulic and pollutant removal performance of fine media stormwater filtration systems. *Environmental Science and Technology*, *42*, 2535–2541. https://doi.org/10.1021/es071264p
Hausmann, S. L., Petermann, J. S., & Rolff, J. (2016). Wild bees as pollinators of city trees. *Insect Conservation and Diversity*, *9*(2), 97–107. https://doi.org/10.1111/icad.12145
Henry, M., & Rodet, G. (2018). Controlling the impact of the managed honeybee on wild bees in protected areas. *Scientific Reports*, *8*, 1–10. https://doi.org/10.1038/s41598-018-27591-y
Herrera, C. M. (2020). Gradual replacement of wild bees by honeybees in flowers of the Mediterranean Basin over the last 50 years. *Proceedings of the Royal Society B Biological Sciences*, *287*, 20192657. https://doi.org/10.1098/rspb.2019.2657
Hill, D. B., & Webster, T. C. (1995). Apiculture and forestry (bees and trees). *Agroforestry Systems*, *29*, 313–320.
Hobhouse, P. (2004). *Plants in garden history*. London: Pavilion Books LTD (First published 1992).
Högberg, M. N., & Högberg, P. (2002). Extramatrical ectomycorrhizal mycelium contributes one-third of microbial biomass and produces, together with associated roots, half the dissolved organic carbon in a forest soil. *New Phytologist*, *154*, 791–795. https://doi.org/10.1046/j.1469-8137.2002.00417.x
Hooper, D. U., Chapin, F. S., Ewel, J. J., Hector, A., Inchausti, P., Lavorel, S., … Wardle, D. A. (2005). Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. *Ecological Monographs*, *75*, 3–35. https://doi.org/10.1890/04-0922
Hou, Y., Burkhard, B., & Müller, F. (2013). Uncertainties in landscape analysis and ecosystem service assessment. *Journal of Environmental Management*, *127*, 117–131. https://doi.org/10.1016/j.jenvman.2012.12.002
Houston, T. (2018). *A guide to native bees of Australia*. Clayton South, Australia: CSIRO PUBLISHING.
Hyvönen, K., Törnroos, K., Salonen, K., Korpela, K., Feldt, T. I., & Kinnunen, U.. (2018). Profiles of nature exposure and outdoor activities associated with occupational well-being among employees. *Frontiers in Psychology*, *9*, 754. https://doi.org/10.3389/fpsyg.2018.00754
IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services* (S. Díaz, J. Settele, E. S. Brondízio, H. T. Ngo, M. Guèze, J. Agard, A. Arneth, P. Balvanera, K. A. Brauman, S. H. M. Butchart, K. M. A. Chan, L. A. Garibaldi, K. Ichii, J. Liu, S. M. Subramanian, G. F. Midgley, P. Miloslavich, Z. Molnár, D. Obura, A. Pfaff, S. Polasky, A. Purvis, J. Razzaque, B. Reyers, R. Roy Chowdhury, Y. J. Shin, I. J. Visseren-Hamakers, K. J. Willis, & C. N. Zayas, Eds.), (p. 56). Bonn, Germany: IPBES secretariat.
John, J., Kernaghan, G., & Lundholm, J. (2016). The potential for mycorrhizae to improve green roof function. *Urban Ecosystems*, *20*(1), 113127. https://doi.org/10.1007/s11252-016-0573-x
Johnson, M. L., Campbell, L. K., Svendsen, E. S., & Silva, P. (2018). Why count trees? Volunteer motivations and experiences with tree monitoring in New York City. *Arboriculture & Urban Forestry*, *44*, 59–72.
Johnson, N. C., & Gehring, C. A. (2007). Mycorrhizas: Symbiotic mediators of rhizosphere and ecosystem processes. In Z. G. Cardon, & J. L. Whitbeck (Eds.), *The rhizosphere, an ecological perspective* (pp. 73–100). San Diego, CA: Elsevier Academic Press.
Kew, R. B. G. (2016). *The state of the world's plants report – 2016*. Kew: Royal Botanic Gardens. https://stateoftheworldsplants.org/2016/report/sotwp_2016.pdf (accessed 05/08/20).
Kilpatrick, J. (2014). *Fathers of botany—the discovery of Chinese plants by European missionaries*. Kew, UK: Kew Publishing Royal Botanic Gardens.
Klein, A. M., Boreux, V., Fornoff, F., Mupepele, A. C., & Pufal, G. (2018). Relevance of wild and managed bees for human well-being. *Current Opinion in Insect Science*, *26*, 82–88. https://doi.org/10.1016/j.cois.2018.02.011
Koch, H., Brown, M. J. F., & Stevenson, P. C. (2017). The role of disease in bee foraging ecology. *Current Opinion in Insect Science*, *21*, 60–67.
Koch, H., Corcoran, C., & Jonker, M. (2011). Honeydew collecting in Malagasy stingless bees (Hymenoptera: Apidae: Meliponini) and observations on competition with invasive ants. *African Entomology*, *19*, 36–41.
Koch, H., & Stevenson, P. C. (2017). Do linden trees kill bees? Reviewing the causes of bee deaths on silver linden (*Tilia tomentosa*). *Biology Letters*, *13*, 20170484. https://doi.org/10.1098/rsbl.2017.0484
Krombein, K. V. (1967). *Trap-nesting wasps and bees: Life histories and nest associates*. Washington, DC: Smithsonian.
Kubiske, M. E., & Abrams, M. D. (1992). Photosynthesis, water relations, and leaf morphology of xeric versus mesic Quercus rubra ecotypes in

central Pennsylvania in relation to moisture stress. *Canadian Journal of Forest Research*, *22*(9), 1402–1407.

Lancaster, R. (2008). *Plantsman´s paradise—travels in China* (3rd ed.). Suffolk, UK: Garden Art Press.

Lanner, J., Kratschmer, S., Petrović, B., Gaulhofer, F., Meimberg, H., & Pachinger, B. (2020). City dwelling wild bees: How communal gardens promote species richness. *Urban Ecosystems*, *23*, 271–288. https://doi.org/10.1007/s11252-019-00902-5

Lawton, E., Brymer, E., Cough, P., & Denovan, A. (2017). The relationship between the physical activity environment, nature relatedness, anxiety, and the psychological well-being benefits of regular exercisers. *Frontiers in Psychology*, *8*, 1058.

Leake, J. R., Johnson, D., Donnelly, D. P., Muckle, G. E., Boddy, L., & Read, D. J. (2004). Networks of power and influence: The role of mycorrhizal mycelium in controlling plant communities and agroecosystem functioning. *Canadian Journal of Botany-Revue Canadienne De Botanique*, *82*, 1016–1045. https://doi.org/10.1139/B04-060

Lehmann, A., & Rillig, M. C. (2015). Understanding mechanisms of soil biota involvement in soil aggregation: A way forward with saprobic fungi? *Soil Biology and Biochemistry*, *88*, 298–302. https://doi.org/10.1016/j.soilbio.2015.06.006

Li, Q. (2010). Effect of forest bathing trips on human immune function. *Environmental Health and Preventive Medicine*, *15*(1), 9–17. https://doi.org/10.1007/s12199-008-0068-3

Lilleskov, E. A., & Bruns, T. D. (2005). Spore dispersal of a resupinate ectomycorrhizal fungus, Tomentella sublilacina, via soil food webs. *Mycologia*, *97*, 762–769. https://doi.org/10.1080/15572536.2006.11832767

Lin, B. B., Philpott, S. M., & Jha, S. (2015). The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. *Basic and Applied Ecology*, *16*(3), 189–201. https://doi.org/10.1016/j.baae.2015.01.005

López-Uribe, M. M., Oi, C. A., & Del Lama, M. A. (2008). Nectar-foraging behavior of Euglossine bees (Hymenoptera: Apidae) in urban areas. *Apidologie*, *39*, 410–418.

Lorenz, S., & Stark, K. (2015). Saving the honeybees in Berlin? A case study of the urban beekeeping boom. *Environmental Sociology*, *1*(2), 116–126.

Lothamer, K., Brown, S. P., Mattox, J. D., & Jumpponen, A. (2014). Comparison of root-associated communities of native and non-native ectomycorrhizal hosts in an urban landscape. *Mycorrhiza*, *24*, 267–280. https://doi.org/10.1007/s00572-013-0539-2

Lowenstein, D. M., Matteson, K. C., & Minor, E. S. (2015). Diversity of wild bees supports pollination services in an urbanized landscape. *Oecologia*, *179*(3), 811–821.

Lyytimäki, J., Petersen, L. K., Normander, B., & Bezák, P. (2008). Nature as a nuisance? Ecosystem services and disservices to urban lifestyle, *Environmental Sciences*, *5*(3), 161–172. https://doi.org/10.1080/15693430802055524

Mach, B. M., & Potter, D. A. (2018). Quantifying bee assemblages and attractiveness of flowering woody landscape plants for urban pollinator conservation. *PLoS One*, *13*(12), e0208428. https://doi.org/10.1371/journal.pone.0208428

MacIvor, J. S. (2016). DNA barcoding to identify leaf preference of leaf-cutting bees. *Royal Society Open Science*, *3*(3), 150623. https://doi.org/10.1098/rsos.150623

Mallinger, R. E., Gaines-Day, H. R., & Gratton, C. (2017). Do managed bees have negative effects on wild bees?: A systematic review of the literature. *PLoS One*, *12*, e0189268. https://doi.org/10.1371/journal.pone.0189268

Marchin, R. M., Sage, E. L., & Ward, J. K. (2008). Population-level variation of *Fraxinus americana* (white ash) is influenced by precipitation differences across the native range. *Tree Physiology*, *28*, 151–159. https://doi.org/10.1093/treephys/28.1.151

Matteson, K. C., Ascher, J. S., & Langellotto, G. A. (2008). Bee richness and abundance in New York City urban gardens. *Annals of the Entomological Society of America*, *101*(1), 140–150. https://doi.org/10.1603/0013-8746(2008)101[140:BRAAIN]2.0.CO;2

Matteson, K. C., & Langellotto, G. A. (2010). Determinates of inner-city butterfly and bee species richness. *Urban Ecosystems*, *13*(3), 333–347.

Mazzeo, N. M., & Torretta, J. P. (2015). Wild bees (Hymenoptera: Apoidea) in an urban botanical garden in Buenos Aires, Argentina. *Studies on Neotropical Fauna and Environment*, *50*, 182–193. https://doi.org/10.1080/01650521.2015.1093764

McLain, R., Poe, M., Hurley, P. T., Lecompte-Mastenbrook, J., & Emery, M. R. (2012). Producing edible landscapes in Seattle's urban forest. *Urban Forestry & Urban Greening*, *11*(2), 187–194. https://doi.org/10.1016/j.ufug.2011.12.002

McPherson, G., & Simpson, J. R. (2003). Potential energy savings in buildings by an urban tree planting programme in California. *Urban Forestry and Urban Greening*, *2*, 73–86. https://doi.org/10.1078/1618-8667-00025

McPherson, G., van Doorn, N., & de Goede, J. (2016). Structure, function and value of street trees in California, USA. *Urban Forestry & Urban Greening*, *17*(1), 104–115. https://doi.org/10.1016/j.ufug.2016.03.013

Michener, C. D. (1979). Biogeography of the bees. *Annals of the Missouri Botanical Garden*, *66*, 277–347.

Molina, R., & Horton, T. R. (2015). Mycorrhiza specificity: Its role in the development and function of common mycelial networks. In T. R. Horton (Ed.), *Mycorrhizal networks* (pp. 1–39). Netherlands, Dordrecht: Springer. https://doi.org/10.1007/978-94-017-7395-9_1

Morgenroth, J., Östberg, J., Konijnendijk van den Bosch, C., Nielsen, A. B., Hauer, R., Sjöman, H., … Jansson, M. (2016). Urban tree diversity – Taking stock and looking ahead. *Urban Forestry and Urban Greening*, *15*, 1–5. https://doi.org/10.1016/j.ufug.2015.11.003

Moro, M. F., & Castro, A. S. F. (2015). A check list of plant species in the urban forestry of Fortaleza, Brazil: Where are the native species in the country of megadiversity? *Urban Ecosystems*, *18*, 47–71. https://doi.org/10.1007/s11252-014-0380-1

Musgrave, T., Gardner, C., & Musgrave, W. (1998). *The plant hunters—two hundred years of adventure and discovery around the world*. England: Ward Lock.

Nemésio, A., Santos, L. M., & Vasconcelos, H. L. (2015). Long-term ecology of orchid bees in an urban forest remnant. *Apidologie*, *46*, 359–368.

Newbound, M., Mccarthy, M. A., & Lebel, T. (2010). Fungi and the urban environment: A review. *Landscape and Urban Planning*, *96*, 138–145. https://doi.org/10.1016/j.landurbplan.2010.04.005

Nguyen, J., & Brymer, E. (2018). Nature-based guided imagery as an intervention for state anxiety. *Frontiers in Psychology*, *9*, 1858. https://doi.org/10.3389/fpsyg.2018.01858

Niedermeier, M., Hartl, A., & Kopp, M. (2017). Prevalence of mental health problems and factors associated with psychological distress in mountain exercisers: A cross-sectional study in Austria. *Frontiers in Psychology*, *8*, 1237. https://doi.org/10.3389/fpsyg.2017.01237

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, *116*, 381–389. https://doi.org/10.1016/S0269-7491(01)00214-7

Nowak, D. J., Pasek, J. E., Sequeira, R. A., Crane, D. E., & Mastro, V. C. (2001). Potential effect of *Anoplophora glabripennis* (Coleoptera: Cerambycidae) on urban trees in the United States. *Journal of Economic Entomology*, *94*, 116–122. https://doi.org/10.1603/0022-0493-94.1.116

Nuñez, M. A., & Dickie, I. A. (2014). Invasive belowground mutualists of woody plants. *Biological Invasions*, *16*, 645–661. https://doi.org/10.1007/s10530-013-0612-y

OpenTrees. (2020). *Datasets on OpenTrees*. Retrieved from www.opentrees.org.

Pataki, D. E., Carreiro, M. M., Cherrier, J., Grulke, N. E., Jennings, V., Pincetl, S., … Zipperer, W. C. (2011). Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions. *Frontiers in Ecology and the Environment*, *9*, 27–36.

Pauleit, S., Zölch, T., Hansen, R., Randrup, T. B., & Konijnendijk van der Bosch, C.. (2017). Nature-based solutions and climate change—four shades of green. In N. Kabisch, H. Korn, J. Stadler, & A. Bonn (Eds.) *Nature-Based solutions to climate change adaptation in urban areas* (pp. 29–49). Dodrecht, The Netherlands: Springer.

Pavao-Zuckerman, M. A. (2008). The nature of urban soils and their role in ecological restoration in cities. *Restoration Ecology*, *16*(4), 642–649. https://doi.org/10.1111/j.1526-100X.2008.00486.x

Pickett, S. T. A., Cadenasso, M. L., Grove, J. M. et al (2001). Urban ecological systems: Linking terrestrial ecological, physical, and socioeconomic components of metropolitan areas. *Annual Review of Ecology and Systematics*, *32*(1), 127–157.

Poe, M. R., McLain, R. J., Emery, M., & Hurley, P. T. (2013). Urban forest justice and the rights to wild foods, medicines, and materials in the city. *Human Ecology*, *41*, 409–422. https://doi.org/10.1007/s10745-013-9572-1

Potschin-Young, M., Haines-Young, R., Görg, C., Heink, U., Jax, K., & Schleyer, C. (2018). Understanding the role of conceptual frameworks: Reading the ecosystem service cascade. *Ecosystem Services*, *29*, 428–440.

Potts, S. G., Imperatriz-Fonseca, V., Ngo, H. T., Aizen, M. A., Biesmeijer, J. C., Breeze, T. D., ... Vanbergen, A. J. (2016). Safeguarding pollinators and their values to human well-being. *Nature*, *540*, 220–229. https://doi.org/10.1038/nature20588

Potts, S. G., Vulliamy, B., Roberts, S., O'Toole, C., Dafni, A., Ne'eman, G., & Willmer, P. (2005). Role of nesting resources in organising diverse bee communities in a Mediterranean landscape. *Ecological Entomology*, *30*(1), 78–85.

Powney, G. D., Carvell, C., Edwards, M., Morris, R. K. A., Roy, H. E., Woodcock, B. A., & Isaac, N. J. B. (2019). Widespread losses of pollinating insects in Britain. *Nature Communications*, *10*, 1018. https://doi.org/10.1038/s41467-019-08974-9

Rathmann, J., Beck, C., Flutura, S., Seiderer, A., Aslan, I., & André, E. (2020). Towards quantifying forest recreation: Exploring outdoor thermal physiology and human well-being along exemplary pathways in a central European urban forest (Augsburg, SE-Germany). *Urban Forestry & Urban Greening*, *49*, 126622. https://doi.org/10.1016/j.ufug.2020.126622

Ratnieks, F. L. W., Piery, M. A., & Cuadriello, I. (1991). The natural nest of the Africanized honey bee (Hymenoptera, Apidae) near Tapachula, Chiapas, Mexico. *Canadian Entomologist*, *123*, 353–359.

Raupp, M. J., Buckelew-Cumming, A., & Raupp, E. C. (2006). Street tree diversity in eastern North America and its potential for tree loss to exotic borers. *Arboriculture and Urban Forestry*, *32*, 297–304.

Requier, F., Garnery, L., Kohl, P. L., Njovu, H. K., Pirk, C. W. W., Crewe, R. M., & Steffan-Dewenter, I. (2019). The conservation of native honey bees is crucial. *Trends in Ecology and Evolution*, *43*, 789–798.

Requier, F., & Leonhardt, S. D. (2020). Beyond flowers: Including non-floral resources in bee conservation schemes. *Journal of Insect Conservation*, *24*, 5–16.

Rewald, B., Holzer, L., & Göransson, H. (2015). Arbuscular mycorrhiza inoculum reduces root respiration and improves biomass accumulation of salt-stressed *Ulmus glabra* seedlings. *Urban Forestry & Urban Greening*, *14*, 432–437. https://doi.org/10.1016/j.ufug.2015.04.011

Reyes-García, V., Menendez-Baceta, G., Aceituno-Mata, L., Acosta-Naranjo, R., Calvet-Mir, L., Domínguez, P., ... Pardo-de-Santayana, M. (2015). From famine foods to delicatessen: Interpreting trends in the use of wild edible plants through cultural ecosystem services". *Ecological Economics*, *120*, 303–311. https://doi.org/10.1016/j.ecolecon.2015.11.003

Richardson, M., & McEwen, K. (2019). 30 Days wild and the relationships between engagement with nature's beauty, nature connectedness and well-being. *Frontiers in Psychology*, *9*, 1500. https://doi.org/10.3389/fpsyg.2018.01500

Rillig, M. C., & Mummey, D. L. (2006). Mycorrhizas and soil structure. *New Phytologist*, *171*, 41–53.

Rimington, W. R., Duckett, J. G., Field, K. J., Bidartondo, M. I., & Pressel, S. (2020). The distribution and evolution of fungal symbioses in ancient lineages of land plants. *Mycorrhiza*, *30*, 23–49. https://doi.org/10.1007/s00572-020-00938-y

Ropars, L., Affre, L., Schurr, L., Flacher, F., Genoud, D., Mutillod, C., & Geslin, B. (2020). Land cover composition, local plant community composition and honeybee colony density affect wild bee species assemblages in a Mediterranean biodiversity hotspot. *Acta Oecologica*, *104*, 103546. https://doi.org/10.1016/j.actao.2020.103546

Ropars, L., Dajoz, I., Fontaine, C., Muratet, A., & Geslin, B. (2019). Wild pollinator activity negatively related to honeybee colony densities in urban context. *PLoS One*, *14*(9), e0222316. https://doi.org/10.1371/journal.pone.0222316

Roubik, D. W. (1992). *Ecology and natural history of tropical bees*. Cambridge, UK: Cambridge University Press.

Sæbø, A., Borzan, Ž., Ducatillion, C., Hatzistathis, A., Lagerström, T., Supuka, J., & Van Slycken, J. (2005). The selection of plant materials for street trees, park trees and urban woodland. *Urban Forests and Trees*, 257–280. https://doi.org/10.1007/3-540-27684-x_11

Sanderson, E. W., Walston, J., & Robinson, J. B. (2015). From bottleneck to breakthrough: Urbanization and the future of biodiversity conservation. *BioScience*, *68*, 412–426. https://doi.org/10.1093/biosci/biy039

Sandström, U. G., Angelstam, P., & Mikusiński, G. (2006). Ecological diversity of birds in relation to the structure of urban green space. *Landscape and Urban Planning*, *77*(1–2), 39–53. https://doi.org/10.1016/j.landurbplan.2005.01.004

Saure, C. (1996). Urban habitats for bees: The example of the city of Berlin. In A. Matheson, S. L. Buchmann, C. O'Toole, P. Westrich, I. H. Williams (Eds.), *The Conservation of Bees, number 18 in Linnean Society Symposium* (Chapter 4; pp. 47–53). Cambridge, MA: Academic Press.

Schebella, M. F., Weber, D., Schultz, L., & Weinstein, P. (2020). The nature of reality: Human stress recovery during exposure to biodiverse, multisensory virtual environments. *International Journal of Environmental Research and Public Health*, *17*, 56. https://doi.org/10.3390/ijerph17010056

Schuldt, B., Knutzen, F., Delzon, S., Jansen, S., Müller-Haubold, H., Burlett, R., ... Leuschner, C. (2016). How adaptable is the hydraulic system of European beech in the face of climate change-related precipitation reduction? *New Phytologist*, *210*(2), 443–458. https://doi.org/10.1111/nph.13798

Senapathi, D., Carvalheiro, L. G., Biesmeijer, J. C., Dodson, C.-A., Evans, R. L., McKerchar, M., ... Potts, S. G. (2015). The impact of over 80 years of land cover changes on bee and wasp pollinator communities in England. *Proceedings of the Royal Society B Biological Sciences*, *282*, 20150294. https://doi.org/10.1098/rspb.2015.0294

Seto, K. C., Guneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences USA*, *109*, 16083–16088. https://doi.org/10.1073/pnas.1211658109

Seto, K. C., Reenberg, A., Boone, C. G., Fragkias, M., Haase, D., Langanke, T., ... Simon, D. (2012). Urban land teleconnections and sustainability. *Proceedings of the National Academy of Sciences*, *109*(20), 7687–7692.

Shanghai 1.2 Million Tree Planting Project. (2020). *Shanghai 1.2 million tree project*. Accessed 05/26/2020. https://www.esrag.org/rc-shanghai-12-million-tree-planting-project.

Sharma, M., Herne, D., Byrne, J., & Kin, P. G. (1996). Nutrient discharge beneath urban lawns to a sandy coastal aquifer, Perth, Western Australia. *Hydrogeology Journal*, *4*, 103–117. https://doi.org/10.1007/s100400050100

Simard, S. W., Beiler, K. J., Bingham, M. A., Deslippe, J. R., Philip, L. J., & Teste, F. P. (2012). Mycorrhizal networks: Mechanisms, ecology and modelling. *Fungal Biology Reviews*, *26*, 39–60. https://doi.org/10.1016/j.fbr.2012.01.001

Sinclair, W. A., & Lyon, H. H. (2005). *Diseases of trees and shrubs* (2nd ed.). Ithaca: Cornell University Press.

Singh, R., Levitt, A. L., Rajotte, E. G., Holmes, E. C., Ostiguy, N., Vanengelsdorp, D., … Cox-Foster, D. L. (2010). RNA viruses in hymenopteran pollinators: Evidence of inter-Taxa virus transmission via pollen and potential impact on non-Apis hymenopteran species. *PLoS One*, *5*, e14357. https://doi.org/10.1371/journal.pone.0014357

Sirohi, M. H., Jackson, J., Edwards, M., & Ollerton, J. (2015). Diversity and abundance of solitary and primitively eusocial bees in an urban centre: A case study from Northampton (England). *Journal of Insect Conservation*, *19*, 487–500. https://doi.org/10.1007/s10841-015-9769-2

Sjöman, H., Hirons, A., & Bassuk, N. L. (2015). Urban forest resilience through tree selection—Variation in drought tolerance in Acer. *Urban Forestry and Urban Greening*, *14*, 858–865. https://doi.org/10.1016/j.ufug.2015.08.004

Sjöman, H., Hirons, A., & Bassuk, N. L. (2018). Improving confidence in tree species selection for challenging urban sites: A role for leaf turgor loss. *Urban Ecosystems*, *21*, 1171–1188.

Sjöman, H., & Östberg, J. (2019). Vulnerability of ten major Nordic cities to potential tree losses caused by longhorned beetles. *Urban Ecosystems*, *22*, 385–395. https://doi.org/10.1007/s11252-019-0824-8

Sjöman, H., Östberg, J., & Nilsson, J. (2014). Review of host trees for the wood boring pests *Anoplophora glabripennis* and *Anoplophora chinensis*: An urban Forest perspective. *Arboriculture & Urban Forestry*, *40*, 143–164.

Smith, R. M., Warren, P. H., Thompson, K., & Gaston, K. J. (2006). Urban domestic gardens (VI): Environmental correlates of invertebrate species richness. *Biodiversity & Conservation*, *15*(8), 2415–2438. https://doi.org/10.1007/s10531-004-5014-0

Smith, S. E., & Read, D. J. (2008). *Mycorrhizal symbiosis* (3rd ed.) (pp. 114–135). London: Academic Press.

Smith, T. J., & Saunders, M. E. (2016). Honeybees: The queens of mass media, despite minority rule among insect pollinators. *Insect Conservation and Diversity*, *9*, 384–390. https://doi.org/10.1111/icad.12178

Somme, L., Moquet, L., Quinet, M., Vanderplanck, M., Michez, D., Lognay, G., & Jacquemart, A. L. (2016). Food in a row: Urban trees offer valuable floral resources to pollinating insects. *Urban Ecosystems*, *19*(3), 1149–1161. https://doi.org/10.1007/s11252-016-0555-z

Sponsler, D. B., Shump, D., Richardson, R. T., & Grozinger, C. M. (2020). Characterizing the floral resources of a North American metropolis using a honey bee foraging assay. *Ecosphere*, *11*, e03102.

Stabler, L. B., Martin, C., & Stutz, J. C. (2001). Effect of urban expansion on arbuscular mycorrhizal fungal mediation of landscape tree growth. *Journal of Arboriculture*, *27*(4), 193–202.

Stara, K., Tsiakiris, R., & Wong, J. L. G. (2015). Valuing trees in a changing landscape: A case study from Northwestern Greece. *Human Ecology*, *43*, 153–167. https://doi.org/10.1007/s10745-014-9706-0

Stevenson, P. C. (2019). To bee-keep or not to Bee-keep: That's the question for UK towns and cities. *The Planner*, *8*, 16. https://www.theplanner.co.uk/opinion/to-beekeep-or-not-to-beekeep-that's-the-question-for-uk-towns-and-cities

Sumner, S., Law, G., & Cini, A. (2018). Why we love bees and hate wasps. *Ecological Entomology*, *43*(6), 836–845.

Szabó, K., Böll, S., & Erös-Honti, Z. (2014). Applying artificial mycorrhizae in planting urban trees. *Applied Ecology and Environmental Research*, *12*(4), 835–853. https://doi.org/10.15666/aeer/1204_835853

Tagu, D., De Bellis, R., Balestrini, R., De Vries, O. M. H., Piccoli, G., Stocchi, V., … Martin, F. (2001). Immunolocalization of hydrophobin HYDPt-1 from the ectomycorrhizal basidiomycete *Pisolithus tinctorius* during colonization of *Eucalyptus globulus* roots. *New Phytologist*, *149*, 127–135.

Takayama, N., Korpela, K., Lee, J., Morikawa, T., Tsunetsugu, Y., Park, B. J., … Kagawa, T. (2014). Emotional, restorative and vitalizing effects of forest and urban environments at four sites in Japan. *International Journal of Environmental Research and Public Health*, *11*(7), 7207–7230. https://doi.org/10.3390/ijerph110707207

Tedersoo, L., & Bahram, M. (2019). Mycorrhizal types differ in ecophysiology and alter plant nutrition and soil processes. *Biological Reviews*, *94*, 1857–1880. https://doi.org/10.1111/brv.12538

Tedersoo, L., Bahram, M., & Zobel, M. (2020). How mycorrhizal associations drive plant population and community biology. *Science*, *367*, eaba1223. https://doi.org/10.1126/science.aba1223

TEEB. (2010). *The economics of ecosystems and biodiversity ecological and economic foundations* (K. Pushpam, Ed.). London, UK and Washington, DC: Earthscan.

Teskey, R., Wertin, T., Bauweraerts, I., Ameye, M., McGuire, M.-A., & Steppe, K. (2015). Responses of tree species to heat waves and extreme heat events. *Plant, Cell and Environment*, *38*, 1699–1712. https://doi.org/10.1111/pce.12417

Theodorou, P., Radzevičiūtė, R., Lentendu, G., Kahnt, B., Husemann, M., Bleidorn, C., … Paxton, R. J. (2020). Urban areas as hotspots for bees and pollination but not a panacea for all insects. *Nature Communications*, *11*, 576. https://doi.org/10.1038/s41467-020-14496-6

Theodorou, P., Radzevičiūtė, R., Settele, J., Schweiger, O., Murray, E. T., & Paxton, J. R. (2016). Pollination services enhanced with urbanisation despite increasing pollinator parasitism. *Proceedings of the Royal Society B: Biological Sciences*, *283*(1833), 20160561. rspb.2016.0561

Threlfall, C. G., Walker, K., Williams, N. S. G., Hahs, A. K., Mata, L., Stork, N., & Livesley, S. J. (2015). The conservation value of urban green space habitats for Australian native bee communities. *Biological Conservation*, *187*, 240–248. https://doi.org/10.1016/j.biocon.2015.05.003

Torné-Noguera, A., Rodrigo, A., Osorio, S., & Bosch, J. (2016). Collateral effects of beekeeping: Impacts on pollen-nectar resources and wild bee communities. *Basic and Applied Ecology*, *17*, 199–209. https://doi.org/10.1016/j.baae.2015.11.004

Transportxtra. (2020). *London's new street trees will help to improve air quality*. Retrieved from https://www.transportxtra.com/publications/local-transport-today/news/63268/london-s-new-street-trees-will-help-to-improve-air-quality/.

Tsopelas, P., Santini, A., Wingfield, M. J., & Wilhelm de Beer, Z. (2017). Canker stain: A lethal disease destroying iconic plane trees. *Plant Disease*, *101*(5), 645–658. https://doi.org/10.1094/PDIS-09-16-1235-FE

Twerd, L., & Banaszak-Cibicka, W. (2019). Wastelands: Their attractiveness and importance for preserving the diversity of wild bees in urban areas. *Journal of Insect Conservation*, *23*(3), 573–588.

Tyrväinen, L., Mäkinen, L., & Schipperijn, J. (2005). Tools for mapping social values for urban woodlands and of other green spaces. *Landscape and Urban Planning*, *79*, 5–19. https://doi.org/10.1016/j.landurbplan.2006.03.003

Ugolini, F., Tognetti, R., Raschi, A., & Bacci, L. (2013). *Quercus ilex* L. as bioaccumulator for heavy metals in urban areas: Effectiveness of leaf washing with distilled water and considerations on the trees distance from traffic. *Urban Forestry & Urban Greening*, *12*, 576–584. https://doi.org/10.1016/j.ufug.2013.05.007

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7

USDA Forest Service, 2016USDA Forest Service. (2016). *i-Tree Eco User's Manual v 6.0*. Washington, DC: U.S. Forest Service Northern Research Station (NRS).

van der Heijden, M. G. A., & Horton, T. R. (2009). Socialism in soil? The importance of mycorrhizal fungal networks for facilitation in natural ecosystems. *Journal of Ecology*, *97*, 1139–1150.

van der Heijden, M. G. A., Martin, F. M., Selosse, M.-A., & Sanders, I. R. (2015). Mycorrhizal ecology and evolution: The past, the present, and the future. *New Phytologist*, *205*, 1406–1423. https://doi.org/10.1111/nph.13288

van der Linde, S., Suz, L. M., Orme, C. D. L., Cox, F., Andreae, H., Asi, E., … Bidartondo, M. I. (2018). Environment and host as large-scale controls of ectomycorrhizal fungi. *Nature*, *558*, 243–248. https://doi.org/10.1038/s41586-018-0189-9

Vogt, J., Gillner, S., Hofmann, M., Tharang, A., Dettmann, S., Gerstenberg, T., … Roloff, A. (2017). Citree: A database supporting tree selection for urban areas in temperate climate. *Landscape and Urban Planning*, *157*, 14–25.

Vos, P. E. J., Maiheu, B., Vankerkom, J., & Janssen, S. (2013). Improving local air quality in cities: To tree or not to tree? *Environmental Pollution*, *183*, 113–122. https://doi.org/10.1016/j.envpol.2012.10.021

Vosátka, M., Albrechtová, J., & Patten, R. (2008). The international market development for mycorrhizal technology. In A. Varma (Ed.), *Mycorrhiza*, 3rd ed. (pp. 419–438). Berlin Heidelberg: Springer-Verlag.

Wagner, D. L. (2020). Insect declines in the anthropocene. *Annual Review of Entomology*, *65*, 457–480. https://doi.org/10.1146/annurev-ento-011019-025151

Watson, J. E., & Venter, O. (2017). Ecology: A global plan for nature conservation. *Nature*, *550*, 48. https://doi.org/10.1038/nature24144

Wenzel, A., Grass, I., Belavadi, V. V., & Tscharntke, T. (2020). How urbanization is driving pollinator diversity and pollination – A systematic review. *Biological Conservation*, *241*, 108321.

Westrich, P. (2018). *Die Wildbienen Deutschlands*. Germany: Verlag Eugen Ulmer.

Wildlife Trust. (2020). Retrieved from: https://www.wildlifetrusts.org/habitats/towns-and-gardens (Accessed 05/08/20).

Willis, K. J., & Petrokofsky, G. (2017). The natural capital of city trees. *Science*, *356*, 375–376.

Wood, T. J., Kaplan, I., & Szendrei, Z. (2018). Wild bee pollen diets reveal patterns of seasonal foraging resources for honey bees. *Frontiers in Ecology and Evolution*, *6*, 210.

Wooller, J. J., Barton, J., Gladwell, V. F., & Micklewright, D. (2016). Occlusion of sight, sound and smell during Green Exercise influences mood, perceived exertion and heart rate. *International Journal of Environmental Health Research*, *26*, 267–280. https://doi.org/10.1080/09603123.2015.1109068

Xiao, Q., & McPherson, E. G. (2002). Rainfall interception by Santa Monica's municipal urban forest. *Urban Ecosystems*, *6*, 291–302. https://doi.org/10.1023/B:UECO.0000004828.05143.67

Yang, J., Zhou, J., Ke, Y., & Xiao, J. (2012). Assessing the structure and stability of street trees in Lhasa, China. *Urban Forestry and Urban Greening*, *11*, 432–438. https://doi.org/10.1016/j.ufug.2012.07.002

Ying, T.-S., & Boufford, D. E. (1998). Phytogeography of the Qinling Mountains and a comparison with the flora and vegetation of Japan. In D. E. Boufford, & H. Ohba (Eds.), *Sino-Japanese flora it's characteristics and diversification*, Tokyo, Japan: The University Museum, The University of Tokyo, Bulletin No. 37.

Yotapakdee, T., Asanok, L., Kamyo, T., Norsangsri, T., Karnasuta, N., Navakam, S., & Kaewborisut, C. (2019). Benefits and value of big trees in urban area: A study in Bang Kachao Green Space, Thailand. *Thailand, Environment and Natural Resources Journal*, *17*(1), 33–43. https://doi.org/10.32526/ennrj.17.1.2019.04

Young, R. F. (2011). Planting the living city. *Journal of the American Planning Association*, *77*, 368–381. https://doi.org/10.1080/01944363.2011.616996

Zhu, Y. G., Christie, P., & Laidlaw, A. S. (2001). Uptake of Zn by arbuscular mycorrhizal white clover from Zn-contaminated soil. *Chemosphere*, *42*, 193–199. https://doi.org/10.1016/s0045-6535(00)00125-9

How to cite this article: Stevenson PC, Bidartondo MI, Blackhall-Miles R, et al. The state of the world's urban ecosystems: What can we learn from trees, fungi, and bees?. *Plants, People, Planet*. 2020;2:482–498. https://doi.org/10.1002/ppp3.10143