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Is biodiversity needed for sustainability? A spotlight on urban landscapes

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The current rate and magnitude of biodiversity loss is so great that we are in the midst of the Earth's sixth mass extinction (Turvey and Crees, 2019). The unsustainable consumption of resources by humans is directly and indirectly responsible for losses to not only the taxonomic, but also the functional, phylogenetic, and genetic dimensions of biodiversity (MA, 2005). Because of the consistent causal relationships between human activities and biodiversity loss, a prevailing paradigm has been that human societal development is diametrically opposed to biodiversity conservation.

However, recent work, summarized in the latest Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) report, indicates that the United Nations' (UN) global sustainable development goals (UN, 2015) can be addressed while simultaneously conserving biodiversity (IPBES, 2019). To realize these win–win scenarios, business-as-usual practices need a transformational overhaul to more sustainable activities that are biodiversity friendly, yet this IPBES report implies that biodiversity and human development need not always be at odds. Furthermore, the report indicates that reaching sustainable development goals may be undermined by the erosion of biodiversity (IPBES, 2019). Meaning, biodiversity—explicitly a diversity of life forms—is essential for the efficiency in resource production and waste removal that is the foundation of sustainable development. Under this paradigm, biodiversity shifts from a casualty of human development to an essential ingredient in the sustainable development of human societies. From a conservation standpoint especially, it is appealing to view biodiversity as a savior for humankind; however, major research questions remain regarding how and under what circumstances biodiversity contributes to sustainability.

In this essay, I assert that the mechanistic links between biodiversity and sustainability need to be explored, especially in the context of urban landscapes. Due to high human population densities and resource demands, urban landscapes are a critical location for researching sustainable development solutions that fulfill societal needs without overexploiting resources (Elmqvist et al., 2019). Yet, studies investigating the contribution of biodiversity to sustainability in urban landscapes are scant, possibly due to a perception of cities as being species-poor (Lepczyk et al., 2017). By exploring biodiversity–sustainability relationships in the unique conditions presented by urban landscapes, we can get closer to reaching the UN's global sustainable development goals.

MECHANISTIC LINK BETWEEN BIODIVERSITY AND SUSTAINABILITY

Broadly, the expected link between biodiversity and sustainability is as follows: biodiversity influences the ecosystem functioning and ecosystem services that generate landscape sustainability (Fig. 1). Ecosystem functions are the processes that transfer energy and/

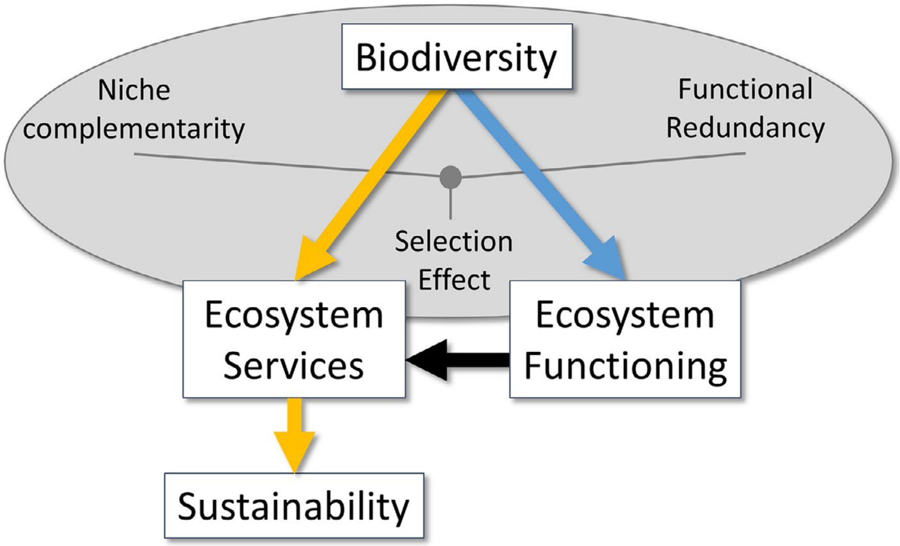

FIGURE 1. Biodiversity contributes to sustainability by influencing the ecosystem functioning and ecosystem services that generate landscape sustainability. Understanding the mechanisms that drive the relationships between biodiversity and ecosystem functioning and ecosystem services (gray oval) is critical in urban landscapes; yet, only the relationships between biodiversity and ecosystem services and between ecosystem services and sustainability have been explored significantly in urban landscapes (yellow arrows). The relationship between biodiversity and ecosystem functioning has been largely explored only in rural (natural, agricultural) landscapes (blue arrow), while the relationship between ecosystem functioning and ecosystem services has been under studied across all landscape types (black arrow).

or information within and between ecosystems (e.g., biomass production, gene flow), and ecosystem services are the outputs from ecosystems, usually resulting from one or many ecosystem functions, that benefit humans (e.g., pollination) (Hooper et al., 2005). A landscape's sustainability is based on its ability to provide consistent ecosystem services into the future and is influenced by the biological, physical, and social components that compose the landscape (Wu, 2013).

From a mechanistic perspective, commonly observed positive correlations between biodiversity (usually measured as species richness) and ecosystem functioning are explained by several mechanisms including niche complementarity, the selection effect, and functional redundancy (Hooper et al., 2005). Under niche complementarity, single species' monocultures have lower functioning than diverse assemblages of species due to synergistic effects among the species when functioning together. In comparison, under the selection effect, diverse assemblages and monocultures of high functioning species have similar levels of functioning, and the positive biodiversity–ecosystem functioning correlation is due to one or a few high performing species that are more likely to be present in species-rich assemblages. Both niche complementarity and selection effect mechanisms assume variation in species' contributions to functioning, but this may not always be the case. Species-rich assemblages can contain functionally redundant species that act to stabilize ecosystem functioning in the face of disturbances that cause species extirpations. Most experimental and observational studies exploring these mechanistic links between biodiversity and ecosystem functioning have been conducted in rural (natural, agricultural) landscapes (Fig. 1) (Plas, 2019). While important, the direct implications and patterns discovered in these studies may have limited transferability to urban landscapes (Schwarz et al., 2017).

Although most ecosystem services are regarded as single or composite ecosystem functions, the full nature of the relationship between ecosystem functioning and ecosystem services has yet to be established (Fig. 1). However, given that most ecosystem services are thought to comprise one or many ecosystem functions, there is an expectation that niche complementarity, the selection effect, and functional redundancy also underlie the relationship between biodiversity and ecosystem services (Fig. 1), yet consistent evidence for these and/or other mechanistic links is still being sought (Duncan et al., 2015). There have been comparatively more explorations of the correlation between biodiversity and ecosystem services in urban landscapes (Ziter, 2016) as well as the spatial configuration of ecosystem services generated across urban landscapes (Lovell and Taylor, 2013), but mechanistic studies are rare (Fig. 1).

BIODIVERSITY FOR SUSTAINABLE URBAN LANDSCAPES

While the entire mechanistic biodiversity–sustainability relationship (Fig. 1) requires research attention in all landscape types, urban landscapes present unique conditions, such as unique species compositions, scales of species turnover, and ecosystem service demands, that require special attention and may generate distinct patterns.

The composition of species in urban landscapes can deviate substantially from rural landscapes; however, the effect of these deviations on ecosystem functioning and ecosystem services has been little explored. Urban environments filter for species such as non-native, ornamental, and generalist species, that can tolerate and exploit urban conditions. Non-native and ornamental species with novel levels of ecosystem functioning not otherwise found in the landscape could possibly skew "natural" patterns of functional redundancy and influence ecosystem resilience. Comparatively, a predominance of generalist species could cause higher functional redundancy relative to rural landscapes. Non-native and ornamental species may also influence the capacity for niche complementarity. Because the community assembly processes in urban landscapes are strongly influenced by humans and do not always result in assemblages of species with a shared co-evolutionary history, niche complementarity may be less likely as a mechanism that maintains ecosystem functioning (Flombaum et al., 2017), but these ideas need further exploration.

Rates and patterns of species turnover in both temporal and spatial dimensions may also vary considerably in urban landscapes, affecting how biodiversity and species compositions are maintained. For example, dispersal in urban landscapes may be altered; animal seed dispersers may be absent or different, and wind dispersal can be dampened or augmented by the urban environment. As such, the temporal scale of species turnover within sites may

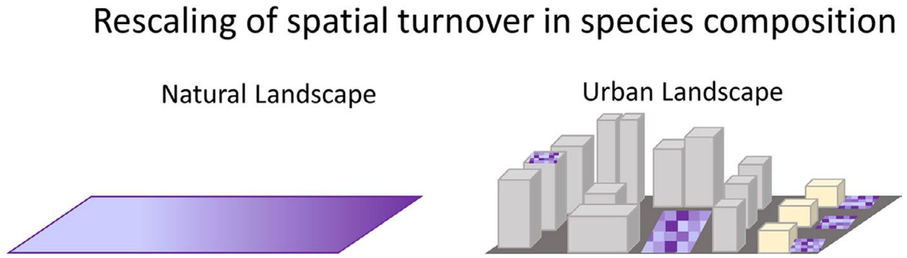

FIGURE 2. The scale of spatial turnover in species composition in urban landscapes can differ from natural landscapes. In this example, both the urban and natural landscapes have the same number of species (colors), but the scale of species turnover is much smaller in the urban landscape. In the natural landscape, species turnover may be driven by a naturally occurring environmental gradient (e.g., moisture, temperature). Comparatively, in the urban landscape where communities are assembled by humans rather than natural processes, a high number of species can be fit into smaller patches of human-managed green infrastructure such as roof gardens, city parks, and residential yards. One possible pattern is displayed here; yet, many other rescaling outcomes are also possible.

happen at vastly different rates than in rural landscapes (Thuring and Dunnett, 2019). Spatially, landscape sustainability can be maintained by spatial heterogeneity in the habitat types and species composition that generate ecosystem services (Plas et al., 2019), and this landscape sustainability is partly dependent on the scale that spatial heterogeneity is measured. Urban landscapes have the potential for high spatial heterogeneity in species composition at smaller spatial scales relative to rural landscapes, especially when human-managed green infrastructure is considered (Fig. 2). Spatial and temporal variation in environmental conditions can also promote niche complementarity and functional redundancy (Loreau et al., 2003), yet species must be able to persist and disperse in the landscape for these effects to be realized, which may be challenging in urban landscapes for some species. Research on how the rescaling of these temporal and spatial processes influences the maintenance of biodiversity and subsequent ecosystem functioning, ecosystem services, and sustainability is sorely needed.

Finally, the constellation of ecosystem services used and valued by residents differs in urban and rural landscapes. Across regions, demand for ecosystem services is highest in urban versus rural landscapes due to high population densities. Urban populations also place a higher importance on regulating services like air and water purification that counteract the waste and pollution urban residents regularly experience that is produced from resource consumption (Martín-López et al., 2012). In addition, the cultural ecosystem services generated by urban green infrastructure can provide benefits such as fewer gun assaults and improved mental health, and these benefits may be enhanced in lower-income neighborhoods (Kondo et al., 2017; South et al., 2018). Because these urban-valued ecosystem services may not be investigated in rural areas, how biodiversity supports these and other services is not well understood.

FUTURE RESEARCH AGENDA

Going forward, to advance this research agenda, mechanistic studies of how biodiversity contributes to ecosystem functioning and ecosystem services in urban landscapes are a critical start. Such studies should directly quantify the strength of ecosystem functioning and services provided by different species assemblages and assess the factors that contribute to community stability and species turnover in urban landscapes. In addition, identifying how biodiversity influences the spatial variation in ecosystem services generated within an urban landscape will provide useful estimates of landscape sustainability. Using this knowledge, then, creative win–win solutions for biodiversity and sustainability can be devised and get us closer to reaching the UN's sustainable development goals.

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LITERATURE CITED

Duncan, C., J. R. Thompson, and N. Pettorelli. 2015. The quest for a mechanistic understanding of biodiversity–ecosystem services relationships. *Proceedings of the Royal Society, B, Biological Sciences* 282: 20151348.

Elmqvist, T., E. Andersson, N. Frantzeskaki, T. McPhearson, P. Olsson, O. Gaffney, K. Takeuchi, and C. Folke. 2019. Sustainability and resilience for transformation in the urban century. *Nature Sustainability* 2: 267–273.

Flombaum, P., R. Aragón, and E. J. Chaneton. 2017. A role for the sampling effect in invaded ecosystems. *Oikos* 126: 1229–1232.

Hooper, D. U., F. S. Chapin, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, et al. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs* 75: 3–35.

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. Bonn, Germany. Website: https://ipbes.net/sites/default/files/2020-02/ipbes_global_assessment_report_summary_for_policymakers_en.pdf.

Kondo, M. C., E. C. South, C. C. Branas, T. S. Richmond, and D. J. Wiebe. 2017. The association between urban tree cover and gun assault: a case-control and case-crossover study. *American Journal of Epidemiology* 186: 289–296.

Lepczyk, C. A., M. F. J. Aronson, K. L. Evans, M. A. Goddard, S. B. Lerman, and J. S. MacIvor. 2017. Biodiversity in the city: fundamental questions for understanding the ecology of urban green spaces for biodiversity conservation. *BioScience* 67: 799–807.

Loreau, M., N. Mouquet, and A. Gonzalez. 2003. Biodiversity as spatial insurance in heterogeneous landscapes. *Proceedings of the National Academy of Sciences, USA* 100: 12765–12770.

Lovell, S. T., and J. R. Taylor. 2013. Supplying urban ecosystem services through multifunctional green infrastructure in the United States. *Landscape Ecology* 28: 1447–1463.

MA. 2005. Ecosystems and human well-being: synthesis. Millennium Ecosystem Assessment, Island Press, Washington, D.C., USA. Website: http://www.millenniumassessment.org/documents/document.356.aspx.pdf.

Martín-López, B., I. Iniesta-Arandia, M. García-Llorente, I. Palomo, I. Casado-Arzuaga, D. G. D. Amo, E. Gómez-Baggethun, et al. 2012. Uncovering ecosystem service bundles through social preferences. *PLoS ONE* 7: e38970.

Plas, F. van der. 2019. Biodiversity and ecosystem functioning in naturally assembled communities. *Biological Reviews* 94: 1220–1245.

Plas, F., E. Allan, M. Fischer, F. Alt, H. Arndt, J. Binkenstein, S. Blaser, et al. 2019. Towards the development of general rules describing landscape heterogeneity–multifunctionality relationships. *Journal of Applied Ecology* 56: 168–179.

Schwarz, N., M. Moretti, M. N. Bugalho, Z. G. Davies, D. Haase, J. Hack, A. Hof, et al. 2017. Understanding biodiversity–ecosystem service relationships in urban areas: a comprehensive literature review. *Ecosystem Services* 27: 161–171.

South, E. C., B. C. Hohl, M. C. Kondo, J. M. MacDonald, and C. C. Branas. 2018. Effect of greening vacant land on mental health of community-dwelling adults: a cluster randomized trial. *JAMA Network Open* 1: e180298.

Thuring, C. E., and N. P. Dunnett. 2019. Persistence, loss and gain: characterising mature green roof vegetation by functional composition. *Landscape and Urban Planning* 185: 228–236.

Turvey, S. T., and J. J. Crees. 2019. Extinction in the Anthropocene. *Current Biology* 29: R982–R986.

UN. 2015. Transforming our world: The 2030 agenda for sustainable development. Springer, New York, NY, USA.

Wu, J. 2013. Landscape sustainability science: ecosystem services and human well-being in changing landscapes. *Landscape Ecology* 28: 999–1023.

Ziter, C. 2016. The biodiversity–ecosystem service relationship in urban areas: a quantitative review. *Oikos* 125: 761–768.