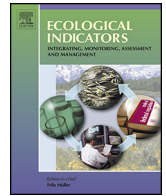




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# Exploring the links between functional traits and cultural ecosystem services to enhance urban ecosystem management

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### ABSTRACT

Functional traits have been proposed as a more mechanistic way than species data alone to connect biodiversity to ecosystem processes and function in ecological research. Recently, this framework has also been broadened to include connections of traits to ecosystem services. While many links between traits and ecosystem processes/functions are easily and logically extended to regulating, supporting, and provisioning services, connections to cultural services have not yet been dealt with in depth. We argue that addressing this gap may involve a renegotiation of what have traditionally been considered traits, and a targeted effort to include and expand upon efforts to address traits-cultural ecosystem services links in traits research. Traits may also offer a better way to explore the recognition and appreciation of biodiversity. Drawing upon examples from outside the explicit traits literature, we present a number of potential connections between functional traits and cultural ecosystem services for attention in future research. Finally, we explore considerations and implications of employing a traits approach in urban areas, and examine how connections between traits and ecosystem services could be developed as indicators in a research and management context to generate a robust and resilient supply of ecosystem services.

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## 1. Introduction

### 1.1. Functional traits and ecosystem services in urban areas

Current urban planning – where it addresses biotic elements – is often geared toward protected areas and parks (rather than the full complexity of the urban matrix) and frequently concentrates on the preservation of charismatic or endangered species. While such approaches can be useful for the conservation of well-recognized species, they do not necessarily succeed in preserving urban ecosystem function or ecosystem service provision in cities, and are unfounded in cases where species diversity does not necessarily correlate with ecosystem service delivery (Naidoo et al., 2008). It has been suggested that a functional trait approach – which describes species by characteristics that impact upon ecosystem function, and, correspondingly, can be related to ecosystem

services (Díaz and Cabido, 2001) – may be a more mechanistic and useful way to interpret the complexity of the urban landscape and manage for urban ecosystem service integrity (e.g., Grime, 1997; Loreau et al., 2001; Flynn et al., 2009). It has also been proposed that a functional traits approach will form an important part of moving beyond the “low-hanging fruit” of future urban biodiversity research to provide biodiversity information of relevance to planners and decision-makers (McDonnell and Hahs, 2013). Functional traits have been discussed in terms of *response traits* (characteristics determining an organism’s response to environmental filters or pressures) and *effect traits* (characteristics of an organism that impact upon ecosystem processes or services) (Díaz and Cabido, 2001; Lavorel and Garnier, 2002; de Bello et al., 2010).

Relatively recent in the traits literature is the extension of the definition of “effect trait” to explicitly encompass not only ecosystem processes/functions, but also ecosystem services (e.g., Díaz and Cabido, 2001; Díaz et al., 2007; de Bello et al., 2010; Lavorel et al., 2011). Building on this evolving definition, in a broad review, de Bello et al. (2010) highlight 247 studies in which empirical connections can be drawn between functional traits and ecosystem services, and specifically document 548 traits-service connections (see Fig. 4 in de Bello et al. (2010) for the most commonly

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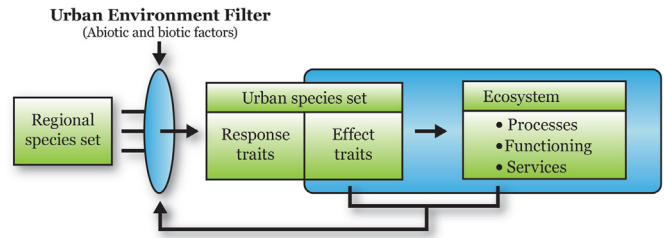
investigated plant and invertebrate traits and their connection to ecosystem services). Notable, however, are two distinct coverage gaps in this collection of literature, one in ecosystem itself, and one in ecosystem service category. While relationships between traits and services are recorded for a range of ecosystems, urban ecosystems are strikingly absent (de Bello et al., 2010, Fig. 1). And in terms of the ecosystem service category, cultural ecosystem services are documented much less frequently in the literature (de Bello et al., 2010, Table 1).

A functional trait approach to management may prove of particular importance and utility in urban ecosystems; a lower proportion of natural elements in cities (as compared with exurban locations) implies that there are fewer areas available that can provide ecosystem services, and hence this provision must be carefully managed. Pressure is further added by the increased (and increasing) density of people that may use and depend upon services in urban areas as compared to more exurban ones. With more than 60% of the world's population predicted to live in cities by 2030 (UN-Habitat, 2008) and approximately 60% of the globe's entire urban extent in 2030 being built in the 30 years prior (2000–2030), we currently face the largest and fastest expansion of cities in all of human history (Elmqvist et al., 2013). Urban systems are hybrid systems of built and living environment and could be designed and managed to provide multiple ecosystem services simultaneously: for example, soil erosion control, water regulation, and aesthetic enjoyment. This kind of design and planning requires a good evidence base of how traits and services are related, as particular traits could then be selected for in order to provide desired ecosystem services and avoid disservices. In this way, traits could serve as useful indicators or proxies for potential ecosystem service provision in the landscape. A traits approach also allows for comparisons of trait-service provision across urban areas.

### 1.2. Drawing connections between functional traits and cultural ecosystem services

This article aims to address the literature gaps described above through an exploratory literature examination of the relationship between cultural ecosystem services and functional traits/characteristics relevant in an urban setting. Our goal is to uncover an array of potential trait-cultural ecosystem service linkages for further examination and testing in urban research and management applications. We choose to hone in on cultural ecosystem services because we believe that the connections of traits to provisioning, regulating, and supporting services that de Bello et al. (2010) outline could already be widely applicable and relevant for urban systems. In terms of organisms, we primarily focus on functional traits of *plants* and *birds*; we elected this focus in order to provide detailed analysis on two meaningful and conspicuous taxa for humans in urban areas. Our review departs from de Bello et al. (2010) in that we cast a broader net, drawing from outside of the explicit traits literature to identify particular plant and bird characteristics that can be related to specific cultural ecosystem services. Our analysis utilizes the categories of cultural ecosystem services that have been identified for the The Economics of Ecosystems and Biodiversity (TEEB) and the Millennium Ecosystem Assessment (MEA) (TEEB, 2010, 2016; MEA, 2003).

Our overarching framework for our understanding of functional trait-ecosystem service links is depicted in Fig. 1 (adapted and modified from Lavorel and Garnier, 2002; Suding et al., 2008), in which a regional species pool is acted upon by an environmental filter of urban conditions/stressors, which filters for certain *response traits* and produces an urban species pool. In the urban setting, human influence plays a key role (Williams et al., 2009; Pataki et al., 2013; Hope et al., 2003; Martin et al., 2004) since humans frequently choose organisms and select for particular traits such as



**Fig. 1.** Framework presenting the relationship between functional traits and ecosystem services in urban ecosystems. This article focuses on the boxed section of the framework in which the effect traits of an urban species set generate ecosystem services.

flowering (e.g., Kendal et al., 2012) based on their needs and preferences. The resultant urban species pool then impacts upon ecosystem processes, functioning, and services through particular *effect traits*. These ecosystem processes, functioning, and services may then, in turn, become part of the filter that impacts upon response traits; this creates a feedback loop of effects in the system. For this article, we will focus on the boxed section of linkages between effect traits and ecosystem services in urban ecosystems (Fig. 1).

Following our presentation of the literature, we synthesize key findings and gaps from the results in order to identify directions for future research. We also highlight two important additional conceptual issues to consider as we take research forward, including trait definitions and unique particularities of working with traits-ecosystem service linkages in urban environments. Finally, we consider how these trait-cultural ecosystem service connections could be incorporated into an indicators tool used for urban environmental management and planning that aims for a resilient supply of multiple ecosystem services.

## 2. Methods

The approach to the literature review included searches run in ISI Web of Science and Google Scholar for terms used to connect specific *effect traits* to *ecosystem processes* or *ecosystem services*. Beyond a general query for the terms highlighted above, in another search, we focused in on particular cultural ecosystem services and generated different combinations of search terms that would draw out literature connecting specific plant and bird characteristics/qualities (i.e., traits) to cultural ecosystem services. We generated additional keywords connected to each cultural ecosystem service of interest. We used the list of ecosystem services as characterized in TEEB and the MEA (TEEB, 2010, 2016; MEA, 2003, pp. 56–60). To generate a detailed range of literature connecting *plant traits* and *bird traits* to *cultural ecosystem services*, topic search terms including the following were used in varying combination:

- cultural ecosystem services(s); aesthetic; spiritual; recreation; cultural; health; wellbeing
- plant(s); vegetation; foliage; flower(s) or bird(s)
- sensation; visual; appearance; color; hue; structure; auditory; sound; song; olfactory; scent; smell; aroma; tactile; touch; gustatory; taste; edibility
- preference(s); value(s); attitude(s)
- human(s); people
- urban; city; cities

In addition to the studies found using the above approach, some were added through (1) reference lists within search-selected papers (i.e., snowballing), and (2) author prior knowledge. Specifically, we attempted to draw upon literature that made explicit

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