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Research paper

Biodiversity and functional diversity of Australian stormwater biofilter plant communities

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A B S T R A C T

Stormwater biofilters are an important part of the urban landscape in many Australian cities. Until recently, plant species have been selected primarily for their survivability and aesthetics. However, recent research has identified specific species that enhance biofilter functions such as pollutant removal and flood prevention (via infiltration). Prior to these findings, little attention was paid to developing planting plans that included plant species with specific functional traits, such as specific root length (SRL), percent fine roots (PFR), and relative growth rate (RGR); rather, biofilter planting plans often suggest planting a relatively large number of plant species with the expectation that some species will not survive due to competition and environmental factors. As these unsuited species are lost, species diversity might be expected to be lower in older biofilters. However, it is unknown whether biodiversity or functional diversity (i.e., the diversity of functional traits) actually decreases as biofilters age. To investigate this question, we surveyed plant communities in 32 biofilters along a chronosequence in Melbourne, Perth, and Sydney. From these data, we calculated biodiversity and functional diversity indices from trait (i.e., SRL, PFR, and RGR) data available in the literature for dominant plant species. We found that, although plant species diversity is lower in older biofilters, functional diversity is unaffected by age. These trends suggest biofilter plant communities maintain functional diversity despite losing biodiversity over time. A better understanding of how plant functional traits relate to ecosystem functions would let us design biofilters with better performance and value.

1. Introduction

Plants; the most visible aspect of most green infrastructure, play a significant role in the function of stormwater biofiltration systems (Bratieres, Fletcher, Deletic, & Zinger, 2008; Payne et al., 2014; Read, Wevill, Fletcher, & Deletic, 2008; Read, Fletcher, Wevill, & Deletic, 2009;Zhang, Rengel, Liaghati, Antoniette, & Meney, 2011). Stormwater biofilters are a type of green infrastructure (a.k.a, water sensitive urban design, sustainable urban drainage systems) comprised of planted soil-based filter media that is designed to treat urban runoff before either releasing to the receiving environment, typically 24–72 h following the runoff event, or stored in a cistern for later use, typically for irrigation. Managing urban stormwater runoff using biofiltration can provide multiple ecosystem services (e.g., carbon sequestration, water quality improvement, urban heat mitigation, provision of biodiversity) (Grant et al., 2012; Hatt, Fletcher, & Deletic, 2009; Lundy & Wade, 2011; Wong & Brown, 2009), but we know very little about plant communities in these systems and how they change over time.

Optimizing biofilter design based on ecological theories has not been widely addressed (Levin & Mehring, 2015). The typically positive relationship between biodiversity and ecosystem function (Balvanera et al., 2006; Mace, Norris, & Fitter, 2012; Tilman et al., 1997) may be an important factor in designing ecosystems for specific purposes. Plants can act as ecosystem engineers in biofilters (Levin & Mehring, 2015), and specific plant traits are associated with particular ecosystem functions (Read et al., 2009). Plant species with varying morphologies, physiologies, and growth strategies can form complementary niches with varying effects on the surrounding environment (Levin & Mehring, 2015). In a biofilter, plants such as *Melaleuca ericifolia*, a relatively deep-rooted shrub native to Australia, maintain infiltration rates over

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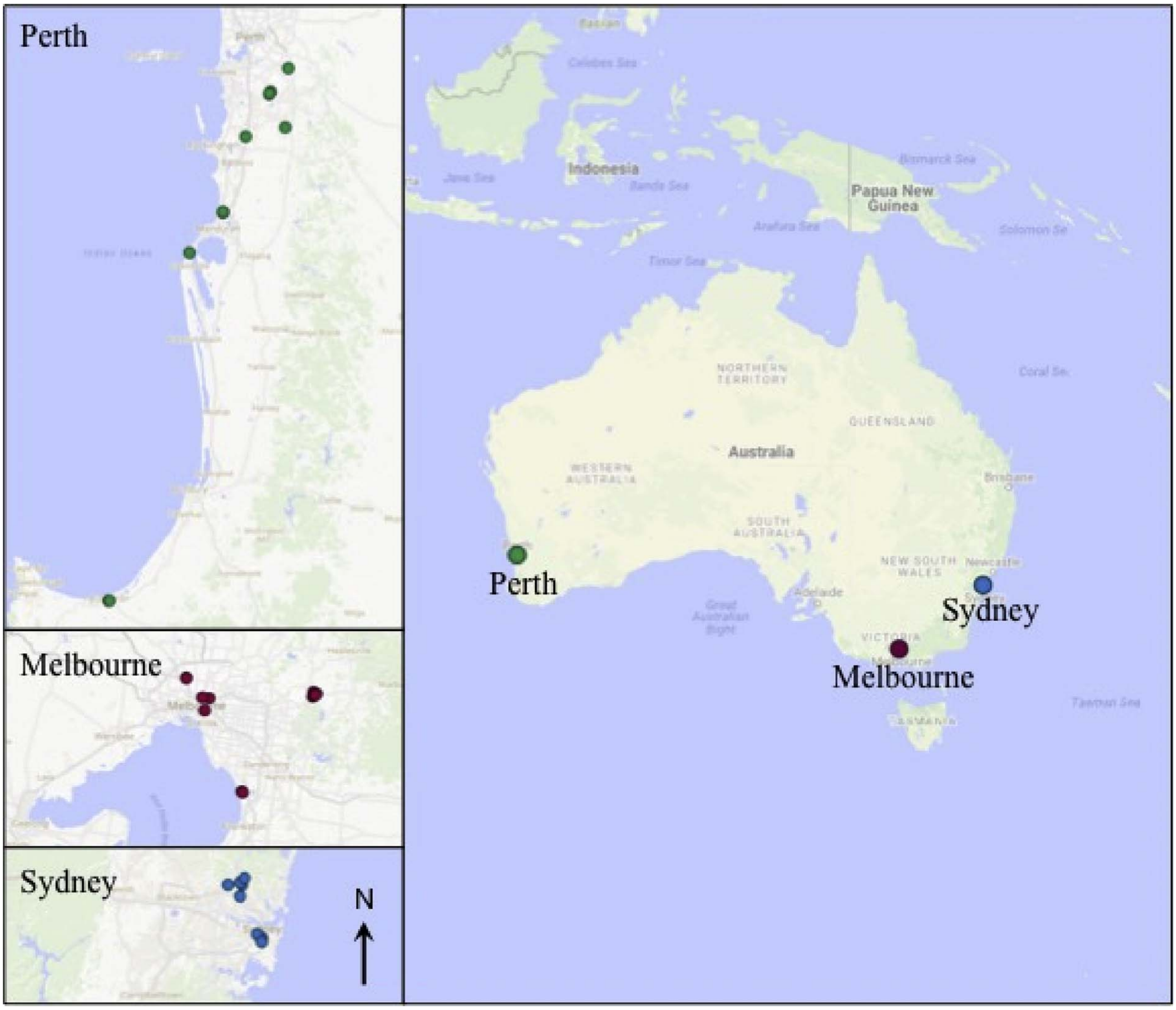

Fig. 1. Location map of biofilters in Melbourne, Perth, and Sydney, Australia. Created using Google Maps.

long periods of time (Le Coustumer, Fletcher, Deletic, Barraud, & Poelsma, 2012) while species like *Carex appressa*, an Australian sedge with a relatively high growth rate and long, fine roots, improve nitrogen removal more efficiently than other species (Read et al., 2009). These plants, with complementary functional traits, can be found growing in the same biofilter in Australia. Planting plans sometimes feature consideration of specific species known to enhance nutrient removal and infiltration, but rarely consider selecting species with specific functional traits explicitly (Payne et al., 2015). This is likely because these traits are not well documented and ecologists are rarely involved in designing green infrastructure (Cameron & Blanuša, 2016).

Plant communities composed of functionally divergent species or traits contain combinations of species that enhance productivity through complementary resource use (Díaz & Cabido, 2001; Petchey & Gaston, 2006). Other ecosystem functions, like pollutant removal and infiltration in biofilters, can be enhanced by specific traits (Payne et al., 2014), such as relative growth rate (Read et al., 2009) and root length (Le Coustumer et al., 2012), respectively. Plant biodiversity and functional diversity measures can be useful tools that managers can use to evaluate biofilters over time. One of these measures, the number of functional groups, is positively correlated to ecosystem function in green roof plant communities (Lundholm, MacIvor, MacDougall, & Ranalli, 2010). However, functional diversity indices that account for the diversity of species traits may be more informative than functional group richness for determining whether a system provides functions that result in ecosystem services (Lundholm, Tran, & Gebert, 2015). Different functional groups may share similar traits that are functionally relevant, so the number of different functional groups does not necessarily account for these similarities. "Functionally redundant" species, those species sharing functional group classifications, may have important roles in community dynamics (Cadotte, Cavender-Bares, Tilman, & Oakley, 2009), but their presence is not accounted for by counting the total number of functional groups. Additionally, the number of functional groups as a measure of functional diversity can only provide an arbitrary scale for assessing diversity (Petchey & Gaston, 2002). For example, in some classification of functional groups, the difference between trees and grasses is equal to the difference between sedges and grasses. Consequently, functional diversity indices that are based on relative differences between functional traits have been developed (Petchy & Gaston, 2002; Walker, Kinzig, & Langridge, 1999). While functional diversity along an urbanization gradient in green infrastructure has been documented using multiple taxa and functional groups selected based on sensitivity to urbanization (Pinho et al., 2016), the authors found no other studies addressing plant functional diversity in green infrastructure along a chronosequence and no studies investigating plant communities in biofilters, other than in relation to habitat provided for invertebrates (Kazemi, Beecham, & Gibbs, 2011).

In this study, we characterized plant communities in various aged biofilters located in three Australian cities with unique climates. To