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Impacts of multiple stressors on ecosystem function: Leaf decomposition in constructed urban wetlands

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ABSTRACT

The impact of stormwater on stream biota is well documented, but less is known about the impacts on ecosystem processes, such as the breakdown of organic matter. This study sought to establish whether the degree of urbanisation affected rates of leaf-litter breakdown within constructed wetlands. A litter bag method was used to ascertain rate of decomposition along a gradient of urbanisation (total imperviousness, TI), in constructed wetlands in western and south-eastern Melbourne. A significant positive relationship between TI and breakdown rate was found in the south-eastern wetlands. The significant reduction in rate of invertebrate-mediated breakdown with increasing concentration of certain metals was consistent with other studies. However, overall there was an increase in rate of breakdown. Studies have shown that the effects of heavy metals can be negated if nutrient levels are high. Our results suggest that other parameters besides exposure to contaminants are likely to affect leaf litter breakdown.

1. Introduction

The increase in the world's population and associated use of resources is causing environmental change at global scales. Aquatic systems are amongst those most severely affected (Aristi et al., 2012). Although the spatial extent of urban developments is fairly low, these areas have a disproportionate effect on ecological systems (Meyer et al., 2005; Grimm et al., 2008; Tippler et al., 2012). Anthropogenic activity generates waste and pollutants and water quality in urban environments is often degraded due to contaminants from catchment surfaces being washed into waterways (Miller and Boulton, 2005; Chadwick et al., 2006; Barbosa et al., 2012). Of particular concern in urban streams are the effects of heavy metals, hydrocarbons and sediment inputs. The impact of urbanisation on stormwater runoff on stream biota has been well documented (Morse et al., 2003; Chadwick et al., 2006; Cuffney et al., 2010). However, less is known about the effect on ecosystem function such as leaf litter breakdown (Chadwick et al., 2006; Imberger et al., 2008).

Macroinvertebrates and fish can be important agents for the bioassessment of stressors such as metal pollution on freshwater systems. However, assessment of ecosystem function is increasingly being used as an alternative approach for determining the health of freshwater systems (Woodward et al., 2010; Niyogi et al., 2013). Breakdown of organic matter gives an insight into microbial communities, energy conversion and aquatic invertebrates. This information is not provided by studying fish and invertebrates alone (Aristi et al., 2012; Niyogi et al., 2013). Accordingly, leaf litter processing rates can be used to assess ecosystem-level anthropogenic impacts on aquatic systems (Woodcock and Huryn, 2005).

Leaf litter breakdown is a complex process involving physical abrasion, colonisation by microbial bacteria and fungi and fragmentation by invertebrate shredders (Woodcock and Huryn, 2005; Aristi et al., 2012). The breakdown of leaf litter by microorganisms to release carbon in a form that is available to invertebrates is an important part of the decomposition process (Fennessy et al., 2008; Medeiros et al., 2010; Aristi et al., 2012) and enables nutrients to be recycled (Fennessy et al., 2008; Medeiros et al., 2010). Leaf litter and other detritus are one of the main basal resources in aquatic systems, providing inputs of particulate and dissolved organic matter (Smucker and Vis, 2011; Aristi et al., 2012). As such, the rate of leaf

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breakdown can have important consequences for the flux of energy through food webs (Medeiros et al., 2010; Fernandes et al., 2011; Aristi et al., 2012).

Aquatic ecosystems in urban environments are subject to many stressors including altered water regimes, altered temperatures, elevated nutrients and the presence of contaminants such as heavy metals (Fig. 1) (Chadwick et al., 2006; Fennessy et al., 2008; Aristi et al., 2012). These factors can influence the rate of leaf litter breakdown, for example, a rise in stormwater inputs can lead to greater sediment supply which increases abrasion and subsequent fragmentation of organic matter (Battle and Golladay, 2001; Fuell et al., 2013). An increase in processing rates has been attributed to increased nutrient runoff and water temperatures in urban areas due to stormwater inflows (Chadwick et al., 2006; Aristi et al., 2012). The amount of stormwater entering aquatic systems is related to the amount of a catchment that is covered in impervious surfaces such as paved areas and roofs, which is known as total imperviousness (TI) (Morse et al., 2003; Walsh et al., 2005; Cuffney et al., 2010). Stormwater runoff can also be a significant source of pollutants (Woodcock and Huryn, 2005).

Constructed wetlands are one method of removing contaminants from urban stormwater and there use is widespread (Nuttall et al., 1997; Batty et al., 2005; Chavan et al., 2007). One of the major mechanisms for this removal is sedimentation (Dunbabin and Bowmer, 1992; Sheoran and Sheoran, 2006; Vymazal et al., 2010). Under certain physical and chemical conditions, metals can become remobilised, therefore the analysis of wetland sediments is essential in determining their potential as a source of pollution (Vymazal et al., 2010; Alhashemi et al., 2011; Lim et al., 2012). The presence of heavy metals can suppress microbial productivity in addition to reducing the presence of macroinvertebrate shredders (Woodcock and Huryn, 2005; Medeiros et al., 2010; Niyogi et al., 2013). This is important as both are critical drivers of decomposition processes in aquatic systems (Fuell et al., 2013).

Most studies of ecosystem processes have been undertaken on streams and rivers, fewer have been conducted in wetland systems, particularly stormwater retention wetlands (Ryder and Horwitz, 1995; Fennessy et al., 2008; Fuell et al., 2013). Fennessy et al. (2008) found that rates of decomposition were lower in constructed wetlands than natural wetlands resulting in less carbon available for assimilation by invertebrates. However, decomposition rates in urban streams have been shown to increase with impervious area (Chadwick et al., 2006; Imberger et al., 2008). The rate at which organic matter is processed can have a significant effect on ecosystem function and biodiversity in aquatic systems (Aristi et al., 2012; Fennessy et al., 2008).

The objective of this study was to determine whether decomposition processes in constructed wetlands in Melbourne, Australia, were correlated with total catchment imperviousness and heavy metal contamination. Our specific aims were to:

1. Ascertain the rate of leaf litter breakdown in constructed wetlands in an urban landscape.
2. Determine if increasing TI is correlated with altered total and microbial breakdown rates.
3. Determine if heavy metal concentrations are correlated with rates of total and microbial breakdown.

As stormwater wetlands are subject to a multitude of stressors, a number of potential outcomes are possible.

1. An increase in impervious area has been associated with an increase in decomposition rates (Imberger et al., 2008) in stream ecosystems.
2. Total imperviousness (TI) has been observed to be positively correlated with heavy metal contamination (Pettigrove and Hoffmann, 2003), which would be expected to be negatively correlated with the rate of decomposition (Gessner and Chauvet, 2002).

2. Materials and methods

2.1. Site selection and calculation of total imperviousness

This study was conducted in the Melbourne metropolitan area, an area of 9800 km^2 in south-east Australia. Land use includes residential, industrial and commercial areas, with a population of

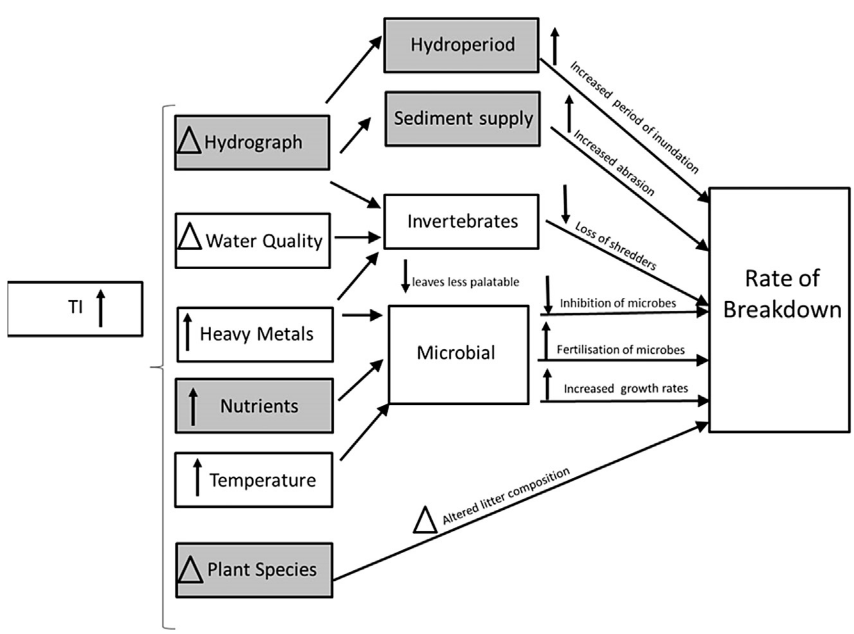

Fig. 1. Schematic representation of the processes that influence the rate of leaf litter breakdown. Arrow indicates direction of effect. Triangles indicate when effect could be in either direction. White boxes indicate parameters measured in this study (Total imperviousness, TI).