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# The influence of urbanisation on macroinvertebrate biodiversity in constructed stormwater wetlands

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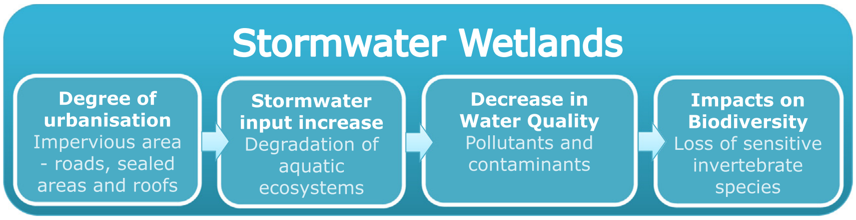
## HIGHLIGHTS

- Constructed stormwater wetlands can provide important habitat for urban wildlife
- Degree of urbanisation, wetland characteristics and invertebrates were analysed
- Tolerant macroinvertebrate species dominated regardless of level of urbanisation
- Prevalence of tolerant species suggests water quality is impaired in these systems
- Dependency between wetland condition and urbanisation detected but impacts can vary

## GRAPHICAL ABSTRACT



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## ABSTRACT

The construction of wetlands in urban environments is primarily carried out to assist in the removal of contaminants from wastewaters; however, these wetlands have the added benefit of providing habitat for aquatic invertebrates, fish and waterbirds. Stormwater quantity and quality is directly related to impervious area (roads, sealed areas, roofs) in the catchment. As a consequence, it would be expected that impervious area would be related to contaminant load and biodiversity in receiving waters such as urban wetlands. This study aimed to establish whether the degree of urbanisation and its associated changes to stormwater runoff affected macroinvertebrate richness and abundance within constructed wetlands. Urban wetlands in Melbourne's west and south east were sampled along a gradient of urbanisation. There was a significant negative relationship between total imperviousness (TI) and the abundance of aquatic invertebrates detected for sites in the west, but not in the south east. However macroinvertebrate communities were relatively homogenous both within and between all study wetlands. Chironomidae (non-biting midges) was the most abundant family recorded at the majority of sites. Chironomids are able to tolerate a wide array of environmental conditions, including eutrophic and anoxic conditions. Their prevalence suggests that water quality is impaired in these systems, regardless of degree of urbanisation, although the causal mechanism is unclear. These results show some dependency between receiving wetland condition and the degree of urbanisation of the catchment, but suggest that other factors may be as important in determining the value of urban wetlands as habitat for wildlife.

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## 1. Introduction

Urbanisation is occurring at a rapid pace, with 66% of the world's population expected to be living in urban areas by 2050 (United Nations, 2014). The effects of urbanisation can also be felt beyond cities with indirect impacts on biogeochemical cycles, hydrological cycles, biodiversity and climate change transformation (Paul and Meyer, 2001; Grimm et al., 2008). As most towns and cities have been established adjacent to supplies of fresh water, rivers and stream ecosystems are particularly severely impacted by urbanisation (Miller and Boulton, 2005; Catford et al., 2007; Hughes et al., 2014).

In urbanised catchments, 'constructed wetlands' are used to remove contaminants, pollutants and nutrients from stormwater to improve the condition of downstream ecosystems (Palmer et al., 2014; Smucker and Detenbeck, 2014). In addition, these wetlands have the benefit of providing habitat for native flora and fauna such as aquatic plants, aquatic invertebrates, fish, amphibians and birds (Ehrenfeld, 2000; Sundaravadivel and Vigneswaran, 2001; Grimm et al., 2008).

Few studies have reported about the effects on increasing catchment imperviousness on macroinvertebrates in urban wetlands (Pankratz et al., 2007; O'Connor et al., 2012; Briers, 2014). This is important as stormwater entering urban streams will often pass through constructed wetlands. The percentage of a catchment which is covered by impervious surfaces can be calculated as total imperviousness (TI) (Morse et al., 2003; Cuffney et al., 2010; Walsh et al., 2005). It is an important variable in the design of constructed wetlands because it can indicate pollutant loading rate and predict the hydraulic effectiveness of the wetland (Melbourne Water, 2015). Although a simplification of the processes occurring, total imperviousness can therefore be used as a potential index to indicate the load of contaminants entering a wetland as these are primarily sourced from impervious surfaces (Schiff and Benoit, 2007).

Within constructed wetlands, invertebrates are a good indicator of the ability of a wetland environment to support other components of biodiversity such as fish and birds (Batty et al., 2005; Pankratz et al., 2007). Invertebrates process organic material, and are a food source for many organisms in aquatic systems (Vermonden et al., 2009; Mereta et al., 2012). The ability of invertebrates to survive in a constructed wetland depends on the type of species, toxicity of the wastewaters, and availability of suitable habitats. Tolerant taxa typically found in such environments include chironomid midges and oligochaete worms and a range of taxa associated with the water surface film (Batty et al., 2005; Pankratz et al., 2007; O'Connor et al., 2012). Even if water quality targets are reached, the abundance of invertebrates is often lower in constructed wetlands than in natural wetlands (Batty et al., 2005; Awal and Svozil, 2010; Briers, 2014). In addition to water quality, suitability of habitat can also determine the presence of macroinvertebrate taxa in wetland systems (Mereta et al., 2012). For example, the abundance and diversity of aquatic invertebrates has been associated with vegetation cover (Bryant and Papas, 2007; Mereta et al., 2012).

The objective of this study was to determine whether catchment total imperviousness influenced water quality, habitat variables and macroinvertebrate communities in constructed wetlands in Melbourne, Australia. We expected to see a relationship between increasing TI and decreasing water quality, resulting in a negative relationship between TI and macroinvertebrate diversity. However, we also acknowledge that other variables that we were not able to measure, for example, habitat structure, may be responsible for observed biotic patterns.

## 2. Material and methods

### 2.1. Site selection and total imperviousness assessment

The study was conducted in the Melbourne metropolitan region, an area of 9800 km$^2$ in south eastern Australia. This region supports a population of 3.81 million people (73% of the inhabitants of the state of Victoria) and the land use includes residential, industrial and commercial areas (ABS, 2013). The underlying lithology of the region comprises two distinct geological regions: basalt in the west and sedimentary sands in the east and south. This has been shown to be potentially detrimental to aquatic communities due to higher concentrations of heavy metals in sediments located in the basalt region (Pettigrove and Hoffman, 2003).

The study examined 16 constructed and four natural wetlands located across the western basalt and eastern sedimentary regions (Table 1). The constructed wetlands were built between 1997 and 2004, and are managed by a single water utility (Melbourne Water). The management objectives for the construction of the wetlands were largely for the control of nitrogen (Melbourne Water, 2005). As such, they are of a consistent design, with an inlet zone from the stream flowing through a gross pollutant trap and into a ponding area. Water then flows through a vegetated zone and into an outlet pond where it is returned to the stream. The constructed wetlands have been designed to be either 'online' or 'offline' (Table 2). Sites which are online have been built on an existing watercourse and all stormwater entering the system is treated by the wetland. By contrast, sites that are offline allow stormwater water to be diverted from an existing waterway into the wetland during a rain event. These systems have been built with a high flow bypass to which water can be diverted when a maximum level in the wetland is reached and there is a risk of flooding beyond the wetland margins (Melbourne Water, 2005).

The sixteen constructed wetlands were all located in predominantly urban catchments. All study sites in the sedimentary region were located within the Dandenong Creek catchment in south eastern Melbourne, Australia (Table 1). Seven constructed wetlands were chosen because there was published information available for these wetlands (Murray et al., 2013). Two natural wetlands that received stormwater inputs were also sampled. Sites in the basalt region were chosen based on previous published studies (Carew et al., 2007; Pettigrove and Hoffmann, 2005) (Table 1). Two natural sites in the western region, which had not been modified or did not receive stormwater inputs, were chosen after consultation with a local wetland scientist (Steve Sinclair, Arthur Rylah Institute, Melbourne) to act as reference (least disturbed) sites.

The percentage of the catchment upstream of the study wetlands that comprised sealed surfaces, including roads, paths and buildings, was calculated using the method described by Walsh and Kunapo (2009) with data supplied by Melbourne Water and ArcGIS 10 (Environmental Systems Research Institute, Redlands, CA, USA) software. A gradient of TI values was obtained for the 20 wetlands ranging from 0.02 to 47% (Table 2).

All sites were sampled once between November 2011 and January 2012. These dates were selected to encompass the period of maximum abundance of common macroinvertebrate taxa. The natural sites in the western region were sampled once during January 2013. Annual total rainfall for the Melbourne region in 2011 was 862.8 mm, and in 2012 was 618.2 mm (Australian Government Bureau Of Meteorology, AGBM, 2015).

### 2.2. Environmental variables

Turbidity, pH, conductivity, dissolved oxygen (DO) and temperature were recorded *in-situ* at each site using a Horiba U50 Water Quality Checker (Horiba Ltd., Japan). Water quality variables were measured by taking spot measurements once in the outlet zone of each wetland between November 2011 and January 2012. Sampling occurred between 10 am and 4 pm. Area of wetland, macrophyte cover (%) within the wetland, fringing vegetation cover (%) up to 10 m from the wetland edge and distance of outlet from inlet were calculated using Google Earth Pro software (Map data: Google SKMF, 2013). Organic matter collected when invertebrates were filtered through a 500 and 250 μm sieve (see Section 2.3) was separated as 'CPOM' and 'FPOM' fractions,