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Stormwater wetlands for the enhancement of environmental ecosystem services: case studies for two retrofit wetlands in Brisbane, Australia

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A R T I C L E I N F O

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A B S T R A C T

Constructed stormwater wetlands are examples of 'blue–green' ecological engineering in the urban environment providing a range of ecosystem services. A study was undertaken in Brisbane, Australia to examine the enhancement of environmental ecosystem services in 2 retrofit wetlands. Originally concrete drainage channels in existing residential catchments, a series of wetlands and ponds were created i.e. green infrastructure in a brownfield setting. Boardwalks, pathways and interpretive signage were incorporated into the design.

Golden Pond wetland was only 0.2% of the catchment whereas Bridgewater Creek – Bowie's Flat wetland was 0.4% of the catchment. The larger 0.8 ha Bridgewater Creek wetland had an overflow by-pass channel. Water quality (suspended solids and nutrients) and the diversity of aquatic macroinvertebrates were monitored for 2–4 years after construction.

During storm events suspended solids increased at Golden Pond due to resuspension from the high velocities in this small linear flow system. Resuspension was minimised at Bridgewater Creek due to the by-pass channel. During dry weather suspended solids in both wetlands increased due to resuspension from the activity of waterbirds. Both wetlands were effective in reducing nutrient concentrations especially NO_x–N and PO_4–P, attributed to biological uptake; but during dry periods NH_4–N increased within the system. The concept of irreducible background concentrations in wetland systems is discussed.

Open water and aquatic vegetation provided habitats for macroinvertebrates. Species richness increased by more than 50% in both stormwater wetlands, compared to the concrete drains.

Wetland sizing and design are essential parameters for water quality improvement and biodiversity.

1. Introduction

Urbanisation decreases both green (forests and fields) and blue (wetlands and water bodies) space and increases impervious surface area so that rainfall infiltration capacity is reduced and the volume of stormwater runoff is increased. This leads to higher flood peaks in urban waterways with possible flooding and higher loads (concentrations and mass) of contaminants: sediment, nutrients, metals, hydrocarbons, organic micro -pollutants i.e. xenobiotics, pathogens. Many of these contaminants are primary stressors of aquatic ecosystem health (Greenway, 2004; Kadlec and Wallace, 2009; Hvitved-Jacobsen et al., 2010).

Whilst the potential impacts of stormwater runoff, as a non-point source of pollution on water quality (and potential ecosystem health) have been recognised since the 1980's, legislation on stormwater control and the implementation of best management practices (BMP's) were not widely recognised and accepted until the 1990's (US EPA, 1996, 2000; Roy et al., 2008; Hvitved-Jacobsen et al., 2010). In USA best management practises are referred to as low impact development (LID), in Australia as water sensitive urban design (WSUD) and in UK as sustainable urban drainage systems (SUDS).

In Australia the first guidelines for Water Sensitive Urban Design (WSUD) were in Western Australia (Whelans et al., 1994). In Queensland, Brisbane City Council released similar guidelines in 1999 (BCC, 1999a,b). Brisbane City Council (2000) set stringent Water Quality Objectives: 15 mg L^{-1} TSS, 5 mg L^{-1} TVS, 0.65 mg L^{-1} TN, 0.035 mg L^{-1} NH_4–N, 0.13 mg L^{-1} NO_3–N, 0.07 mg L^{-1} TP,

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0.035 mg L^{-1} PO_4–P, 8 μg L^{-1} chlorophyll-a; to meet legislative requirements to improve the quality of stormwater runoff which ultimately flows into Moreton Bay, designated in 1993 as a RAMSAR wetland/marine park with significant fisheries values and international ecological values (Ramsar Information Sheet: Moreton Bay).

Structural BMPs include: Gross Pollutant Traps (to catch coarse sediment and trash), Retention/Detention/Sediment Basins (to capture coarse and fine sediment, and removal of soluble contaminants), Vegetation Buffer Strips (removal by sheet flow across wide natural vegetation strips), Infiltration and Bioretention Systems (removal by physical filtration, chemical and biological processes), Vegetation Filter Strips/Grass Swales (removal along concentrated flow paths), Water Quality Control Ponds/Wet Ponds/Dry Ponds/Wetlands (aquatic ecosystems – contaminant removal assisted by wetland plants, algae and microorganisms) (BCC, 1999a,b; US EPA, 2000; Hvitved-Jacobsen et al., 2010). Although the primary purpose of BMP's was seen as hydrological-controlling runoff flows, flood mitigation, water storage and contaminant removal to improve downstream water quality, it is now recognised that BMP's can be an infrastructure opportunity for the improvement of environmental (habitat and landscape enhancement, biodiversity, ground water protection) and social (recreational amenities, aesthetics, sustainable living) services in urbanised areas (Martin et al., 2007; Roy et al., 2008; Marsalek and Schreier, 2009; Hvitved-Jacobsen et al., 2010; Barbarosa et al., 2012).

Wetlands and ponds are suitable BMP's for both water storage and water quality improvement. Vegetation (emergent aquatic plants) is the dominant feature of wetlands, whereas open water is the dominant feature of ponds (Greenway et al., 2007). Ponds, which include sediment basins, retention/detention ponds are often deeper than 1.5 m and emergent plants are restricted to the shallow littoral margins. Submerged pondweeds may occur if there is sufficient light. The design of stormwater wetlands usually incorporates both zones of dense vegetation (shallow macrophytes zones) and deeper open water (Greenway, 2004; Kadlec and Wallace, 2009). The 'treatment' of stormwater as it flows through a wetland/pond is the result of complex interactions between physical, chemical and biological processes (Greenway, 2004; Kadlec and Wallace, 2009; Hvitved-Jacobsen et al., 2010). Vegetation plays an important role in these processes.

Ponds and wetlands also provide habitats for a range of biota, aquatic plants and animals as well as terrestrial wildlife (Wetzel, 2001; Mitsch and Gosselink, 2007; Cereghino et al., 2014). When constructed in residential areas to treat stormwater these water bodies can potentially balance the detrimental effects of urbanisation on predevelopment landscapes and ecosystems, achieving and sustaining biodiversity. Only recently have studies assessed these ecological values in stormwater wetlands (Woodcock et al., 2010; Tixier et al., 2011; Moore and Hunt, 2012, Herrmann, 2012).

This paper examines the environmental services of water quality improvement and aquatic macroinvertebrate biodiversity provided by 2 stormwater wetlands constructed within existing older residential areas ie new 'green and blue 'infrastructure within old 'brownfield' settings. Both wetlands were created from retrofitting concrete drainage channels. Social values are briefly discussed.

2. Materials and methods

2.1. Wetland descriptions

Two urban stormwater wetland systems were selected with similar catchment size (180 ha) to monitor water quality treatment and aquatic macroinvertebrate biodiversity. Both systems are located in Brisbane, SE Queensland; Australia. The climate is subtropical with an average annual rainfall of 1120 mm. The wet season occurs over summer/autumn, with an average of 10days with greater than 50 mm daily rainfall; intense rainfall events of 1 h duration of 71 mm/h are common. During the study period a 1 in 100 year event occurred when 208 mm fell in 3 h.

The significance of the wetlands selected is that they are both 'retrofit' systems. They were designed and constructed within existing residential estates (brownfield sites) using sections of concrete channelised streambeds.

2.1.1. Golden Pond stormwater treatment wetland system

The Golden Pond system is located in Calamvale-a new (1990's) outer suburb SW of Brisbane. Prior to development three stream channels (tributaries of Calamvale Creek) fed into a series of lagoons with fringing riparian wetlands – known as the Kameruka Wetlands. The main north-south flowing stream tributary has a catchment of 160 ha, whereas the west-east flowing stream tributaries have a combined catchment of 50 ha.

As a consequence of residential development, considerable modification occurred. Initially the main (north-south flowing) stream was channelised into a concrete lined trapezoidal channel. However in 1999 Brisbane City Council decided to 'retrofit' the lower section (120 m) of the concrete channel into a 'linear flow wetland system' including a small sediment basin (20 m × 13 m), a shallow wetland (Wetland1 80 m × 20 m)and a deeper pond (Wetland2 50 m × 20 m) (Fig. 1). Pathways and a picnic shelter in parkland adjacent to Wetland 2 were incorporated into the design. Interpretive signage was erected to increase public awareness of stormwater quality improvement devices (SQIDs).

Stormwater from the concrete sediment basin flows into Wetland 1 (the Wetland) via a v-notched weir. Base flow and storm event discharge rates are given in Table 1. Discharge rates calculated for stormwater leaving the sediment basin and entering Wetland 1 ranged from 3 to 5.7 m^3 s^{-1} for extreme (>20 y ARI) storm events, and from 0.15 to 0.8 m^3 s^{-1} for high-intensity rain squalls. At discharge rates greater than 0.45 m^3 s^{-1}, short-circuiting occurs through the middle due to the positioning of a single V-notch weir, the lack of dense emergent macrophytes, and the linear nature of the flow path through the wetland. There is no bypass channel.

Between Wetland 1 (the Wetland) and Wetland 2 (the Pond), the water flows over a wide concrete sill. Piped underground drainage from the western section of residential development (20 ha) passes through a below ground Gross Pollutant Trap (GPT): CDS Proprietary Unit, before being discharged into Wetland2. Water then flows into Calamvale Creek.

The narrow outlet (1 m width) at the end of Wetland 2 ensures that the water backs up, thereby increasing the retention time. Water storage capacity and detention times are given in Table 1. It has been estimated that the average retention time for both wetlands during non-extreme storm events would be between 3 and 5 h, and between 5 and 32 h for less intense rainfall events.

The total area of this 'constructed wetland system' is 3000 m^2 i.e. 0.2% of the watershed catchment.

Piped drainage from the south western section of residential development (30 ha) also passes through a below ground GPT: ECOSOL Proprietary Unit, before entering the upper reaches of Calamvale Creek within a densely vegetated riparian wetland.

Calamvale Creek, several lagoons and adjacent riparian vegetation - the Kameruka Wetlands were retained in their natural state for a length of 680 m (Fig. 1). Calamvale Creek flows into Scrubby Creek, then the Logan River and into Moreton Bay Ramsar Wetland.

2.1.2. Bridgewater Creek stormwater treatment wetland system: Bowie's Flat Wetland

The Bridgewater Creek system is located at Cooparoo (SE Brisbane). Urbanisation of this suburb and adjacent Camp Hill occurred

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