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People, Politics and Wetlands

1.1 The importance of urban wetlands

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Abstract

Wetlands are important ecosystems globally, however, despite being one of the most productive habitats on Earth they are under threat from urbanisation. With over 50% of the world's population living in cities, draining and infill of wetlands to provide land for residential housing and urban infrastructure is one of the largest causes of wetland loss. Those wetlands that do remain usually function differently to non-urban wetlands due to changes in hydrology, habitat degradation, pollution and the impacts of exotic and invasive species. Urban wetlands often become more important for human-related values than non-urban wetlands. They provide multiple ecosystem services including removing contaminants from wastewater, flood control, biodiversity support, microclimate modification, carbon sequestration, aesthetic amenity and recreational spaces. Wetlands constructed for remediation of urban stormwater are designed to mimic the processes which occur in natural wetlands. Wetlands constructed on stream networks can intercept stormwater runoff and prevent contaminants from reaching downstream surface waters, including estuaries and near-shore marine regions. As these systems are designed to act like natural wetlands they have the added benefit of providing a habitat for wildlife. The magnitude of wetland loss means that these wetlands are often the only systems supporting wildlife in urban environments. Urban wetlands containing permanent water can provide important refugia for many species during dry periods and droughts. Urban wetlands are able to provide local residents with the opportunity to interact with nature through activities such as bird watching. This provides the opportunity for communities to see 'wild' species they may not otherwise encounter. Furthermore, evidence is emerging that access to green spaces in cities is important for psychological health and general wellbeing. In an increasingly urbanised world, wetlands must be managed and valued for the multiple and important goods and services they provide.

Introduction

Wetlands are globally important ecosystems, they are found on every continent and are among the most productive habitats on Earth (Gopal 1999; Zhao and Song 2004). Although they only occupy 6% of the Earth's surface, they support approximately 20% of all living organisms providing an important source of biodiversity (Zhao and Song 2004; Batty *et al.* 2005). In addition, wetlands provide a number of essential ecosystem services. These are defined as the services which benefit human populations, either directly or indirectly (Bouland 1999; Moore and Hunt 2012). Important ecosystem services provided by wetlands include provision of water supplies, biodiversity support, retention of nutrients and pollutants, flood mitigation, modification of microclimates and carbon sequestration (Ellis *et al.* 2003; Sheoran and Sheoran 2006; Speelmans *et al.* 2007). However, despite being such a valuable resource, the world's wetlands are under threat from many pressures, including increasing urbanisation.

The loss of wetlands in urban areas is largely due to the draining of land for residential and commercial development and the establishment of road infrastructure (Boyer and Polasky 2004). Those wetlands which do remain are likely to function differently to non-urban wetlands. Urban wetlands are often located within park settings dominated by non-native plant species, they may act as flood retarding basins or be used to remove contaminants from wastewaters to protect downstream receiving waters (Ehrenfeld 2000). Wetlands in urban areas often become more important for human-related values, especially landscape amenity and recreational values, than those in non-urban areas (Ehrenfeld 2000).

The ability of wetlands to provide ecosystem services such as the purification of wastewater has led to the development of 'constructed' wetlands. These are engineered systems, designed to utilise the natural processes which occur in wetlands (Nuttall *et al.* 1997; Vymazal 2007). These artificial wetlands are often designed to create "generic" wetland habitats which can be used for both flood mitigation and pollution control (Ellis *et al.* 2003; Jin and Lin 2004).

Constructed urban wetlands not only remove contaminants and offer flood protection, but are often an integral part of the cityscape. They provide important habitats for wildlife and offer local residents the opportunity to interact with nature through activities such as bird watching - opportunities which are often limited in urban environments (Boyer and Polasky 2004). Evidence is emerging that access to green spaces, such as wetlands, in urban environments, is important for physical and psychological health and general wellbeing (Dallimer *et al.* 2012; Keniger *et al.* 2013).

The impacts of urbanisation on wetlands

Approximately 50% of the world's population live in cities, and this percentage is predicted to rise to 60% by 2030. The greatest growth will be seen on the continent of Africa where the urban population is anticipated to double from 27% to 54% (Grimm *et al.* 2000; Meyer *et al.* 2005; Cai *et al.* 2012). With only 23 million inhabitants, Australia has a low population density (approximately 0.005 people per hectare). However, it is one of most urbanised countries in the world, with 84% of the population living in urban centres (Miller and Boulton 2005; ABS 2008). Population growth comes with an increasing urban footprint. We have changed our enviroment more in the last 50 years than at any other period in human history (MEA 2005; Meyer *et al.* 2005; Cai *et al.* 2012). This change has been accompanied by an uprecedented increase in human well-being and economic development. Cities have high resource needs and although only 2% of the Earth's surface is developed, urbanisation produces 78% of all greenhouse gases (Grimm *et al.* 2000; Grimm *et al.* 2005; Meyer *et al.* 2005; Cai *et al.* 2012).

Waterways and wetlands have been greatly affected by increasing urbanisation because most towns and cites have been established along rivers and on their adjacent floodplains (Miller and Boulton 2005; Catford *et al.* 2007). The impacts of urbanisation can also be felt beyond cities with indirect impacts on biogeochemical cycles, hydrological cycles, biodiversity, climatic change and land transformation (Grimm *et al.* 2005).

Major urban impacts on wetlands include changes in hydrology, habitat degradation and pollution (Boyer and Polasky 2004; Zhao and Song 2004). Changes in hydrological processes, including the balance between groundwater-dominated and surface water-dominated inputs, and a change from seasonal to permanent water regimes were found to be the major drivers causing eutrophication, acidification and ecological regime change in the urban wetlands of Perth, Western Australia (Davis *et al.* 2010).

Population pressures and accompanying planning inadequacies have had a major role in the loss and degradation of Perth wetlands despite the fact that the region comprises one of the least populated regions of the world. Draining and infilling of wetlands and damplands has occurred to create dry land for housing and urban infrastructure. Fringing vegetation is often removed and wetland habitats destroyed in the process of landscaping wetland areas for use as urban parks. Fragmentation and loss of connectivity has occurred as wetlands that may once have been regularly connected during winter as a result of large scale flooding of low lying areas became isolated as part of the process of draining and infilling (Davis and Froend 1999).

Many Perth wetlands are excessively nutrient enriched (eutrophic) because they receive nutrients in groundwater and surface water inflows from various human activities. Leaking septic tanks in older Perth suburbs contribute nutrients to the aquifers that support inter-dunal wetlands. Fertilizers applied to urban lawns and gardens also contribute nutrients to Perth's wetlands. The feeding of birds at popular urban wetlands contributes to enrichment by artificially maintaining large populations of waterfowl (Davis and Froend 1999). The consequences of nutrient enrichment are well documented and include the development of nuisance algal blooms, odours and anoxic conditions. Waterfowl, fish and large invertebrates may suffer direct lethal effects due to both algal toxicity and periods of reduced oxygen availability. Waterfowl deaths may also occur as a result of outbreaks of botulism, caused by the bacterium, *Clostridium botulinum*, and promoted by anoxic conditions. Outbreaks of nuisance midges (*Polypedilum nubifer*) at Perth wetlands are also driven by the growth and subsequent decay of large algal blooms (Pinder *et al.* 1991).

One of the largest impacts of urbanisation on waterways and wetlands is an increase in the quantity of urban runoff due to an increase in the extent of impervious areas (Table 1.1.1) (Ehrenfeld 2000; Boyer and Polasky 2004; Grimm *et al.* 2008). An increase in impervious area (roads, sealed areas and roofs) results in a decrease in water quality caused by increasing concentrations of nutrients, metals and organic pollutants (Ehrenfeld 2000; Boyer and Polasky 2004; Vermonden *et al.* 2009). Effective Imperviousness (EI) is the measure used to quantify the amount of catchment imperviousness associated with urbanisation. An increase in EI, in conjunction with an increase in the efficiency of drainage connections to stream channels, appears to be the main factor affecting aquatic ecosystems in urban settings. These impacts have been described in terms of a loss of biodiversity and sensitive species in areas of high imperviousness (Walsh *et al.* 2001; Taylor *et al.* 2004; Grimm *et al.* 2005).

Table 1.1.1. Potential impacts of urbanisation on wetland ecosystems (adapted from Ehrenfeld 2000).

Impact	Effect
Hydrology	• An increase in surface runoff results in increased volumes of water entering wetlands • Increased erosion due to increased stormwater runoff results in greater amounts of sediment entering systems • Reduced groundwater recharge, greater range of flow rates means low flows are diminished and the occurrence of a greater number of high flow events
Geomorphology	• Decreased sinuousity of wetlands/upland edge resulting in a decrease in ecotone habitat • Alterations in shape and edge slopes affect water-disseminating properties
Vegetation	• Exotic and invasive species present • Depauperate species pools • Loss of pollinators and fruit dispersers • Biogeochemical changes which impede growth • Fragmentation of natural habitats
Fauna	• Species with small home range and high dispersal rates favoured • Fragmentation of aquatic habitats/loss of connectivity • Absence of upland habitat adjacent to wetlands • Absence of wetland/upland ecotones • Human presence disruptive of normal behaviour

A long term study (6–25 years) of nine seasonal groundwater-dominated wetlands in outer Perth, in southwestern Australia, found that the wetlands were affected by a change in water availability caused by climatic drying and anthropogenic demands for domestic water supply. The aquifer has been subjected to pumping since 1979. Continuous extraction had caused a doubling in the seasonal change in the height of the water table (Yesertener 2002). This combined with the well-documented decline in rainfall has decreased the depth and duration of water in temporary wetlands. Many wetlands in the region no longer filled annually and some that were perennial in the past have become seasonal. However, the aquatic invertebrate communities of these wetlands appear to be able to tolerate some level of extended climatic and anthropogenically-driven drying. A potential explanation for the apparent resilience of the wetland invertebrate fauna is that southwestern Australia has been more arid in the past, with maximum aridity estimated to have occurred during the Last Glacial Maximum, 18,000 years ago (De Deckker and Williams 1986). It seems likely that the decline in annual precipitation recorded to date has not yet exceeded the severity of past aridification (Sim *et al*. 2013).

The increasing fragmentation of urban wetland systems, and the associated loss of connectivity, caused by urban development, has adverse implications for the colonisation and establishment of many species, including fishes and turtles, that exist as regional metapopulations. Urban wetlands are likely to experience increasing exposure to exotic and invasive species, especially under the scenario of a drying climate. The invasive mosquitofish, *Gambusia holbrooki*, is common in many urban wetlands throughout Australia. Other invasive and exotic species found in urban wetlands include the goldfish, *Carassius auratus* and carp, *Cyprinus carpio*. Aquatic snails, such as *Helisoma* sp. and *Physa* sp., have been introduced to urban wetlands when the contents of unwanted home aquariums have been released. Exotic aquarium plants such as *Elodea* spp. have similarly been introduced to urban wetlands.

Exotic and invasive plants have an adverse impact on the composition of indigenous wetland plant communities and the potential for natural recruitment. The emergent macrophyte, *Typha orientalis*, is considered to have displaced native emergent macrophytes in urban wetlands in Western Australia. Exotic grasses (*Stenotaphrum secundatum* and *Cynodon dactylon*) and mesophytic herbaceous weeds are common at many urban wetlands. These exotics smother native understory species, increase the fire risk and limit the potential for the establishment of seedlings of tree species (Davis and Froend 1999).

A warmer climate will facilitate a southward invasion of disease-carrying mosquitoes, with increased incidence of Ross River virus, Murray Valley encephalitis and dengue fever (IPCC 2007). Increased mosquito ranges and increased transmission of disease are associated with higher temperatures and the presence of small isolated waterbodies (Davis *et al*. 2009). Range extensions of warm-water invasive plants including lippia (*Phyla canescens*), arrow-head (*Sagittaria montevidensis*) and water hyacinth (*Eichhornia crassipes*) are likely to occur as global temperatures increase.

Indirect impacts of climatic change are also likely to affect urban wetlands, particularly through interactions with existing stressors. For example, an increase in fox predation on the black swan (*Cygnus atratus*) has occurred at two Ramsar-listed Perth wetlands, due to lower water levels caused by recent declining annual rainfall and increased groundwater extraction (Maher and Davis 2009). A decrease in the annual duration of water at one wetland (Thomson's Lake) enclosed by a vermin-proof fence resulted in cygnets being trapped within the boundary fence because they had not fledged (could not fly) before the wetland dried completely in 2006. Opening a gate allowed cygnets to walk to a nearby deeper wetland. However, the dispersing cygnets became the focus of fox predation once outside the protected wetland. Drying at another wetland (Forrestdale Lake), not protected by a vermin-proof fence, enabled foxes to walk across the dry lakebed to reach swan nests. As a consequence, extremely high levels of predation on eggs and young cygnets has occurred at this lake (Maher and Davis 2009).

Wetlands in urban areas are intrinsically valuable because there are so few remaining. The cost of land in urban environments is often very high and undeveloped land is a scare and valuable commodity. There are often large financial incentives to drain a wetland in order to build houses, or other structures (including shopping centres, offices, schools and hospitals). Although wetlands provide important ecosystem services, it is often hard to place a monetary value on these services because they are typically not sold. As such, where no regulation exists, it is often beneficial for landowners to fill wetlands and benefit from private development (Boyer and Polasky 2004).

The beneficial roles of urban wetlands

Water plays a major role in supporting ecosystem services within urban environments and although urban wetlands are often specifically constructed to fulfil one or two major ecosystem services (nutrient retention and flood control) they potentially support multiple ecosystem services and values (MEA 2005; Bennett *et al.* 2009; Moore and Hunt 2012). The Millennium Ecosystem Assessment Report commissioned by the United Nations Environment Program (2005), categorised ecosystem services into Supporting, Provisioning, Regulating and Cultural components each with a different impact on human well-being (Table 1.1.2).

The need to manage landscapes, including urbanscapes, to provide a wide range of ecosystem services and values is increasing (MEA, 2005). It is also recognized that managing simultaneous ecosystem services is extremely challenging (Bennett *et al.* 2009). The concept of ecosystem services is now being incorporated into environmetal planning and management of urban environments to address this challenge (Moore and Hunt 2012).

Folke *et al.* (2004) defined resilience as 'the capacity of a system to absorb disturbance and reorganize while undergoing change so as to retain essentially the same function, structure, identity, and feedbacks'. Human pressures on ecosystems, largely driven by population growth and the desire to increase economic well-being, have often resulted in degraded ecosystems, and a loss of resilience. New ways of thinking are required to manage resilience in changing environments and to ensure that essential ecosystem services are maintained.

The multiple ecosystem services provided by urban wetlands and waterways include: biodiversity support, microclimate modification, carbon sequestration, nutrient retention, flood control, recreational open space and aesthetic amenity (Table 1.1.3). We need to recognise the drivers of the multiple ecosystem services, and the interactions between services, provided by urban wetlands, to identify where synergies can be maximized and trade-offs reduced. To do this we need to quantify the importance and use of ecosystem services and values provided by urban water. We need to determine the strength of relationships between provisioning and regulating services, and to understand how relationships change with time, scales and management. For example, for wetlands which purify wastewaters from domestic sources there is the potential to use the harvested biomass as a raw material for the paper industry, for use in fertilizers and as a feed supplement for animals. There is even the potential for biomass to be used for fuel production. However, for biomass contaminated with heavy metals, elements would first need to be extracted due to their toxicity (Ciria *et al.* 2005). Urban wetlands also represent an opportunity for carbon sequestion via wetland soils, in addition to contributing to local biodiversity (Moore and Hunt 2012).

Environmental protection

The concept of ecosystem services can be incorporated into the design and management of stormwater infrastructure. In urban environments stormwater wetlands have been constructed to

Table 1.1.2. Ecosystems Services (adapted from MEA 2005).

Service	Description	Examples
Supporting Services	Services that are necessary for the production of other ecosystem services	Soil formation, photosynthesis, primary production, nutrient and water cycling
Provisioning Services	Products obtained from ecosystems	Food, fibre, fuel wood, genetic resources, biochemicals, natural medicines and pharmaceuticals, freshwater
Regulating Services	Benefits obtained from the regulation of ecosystem processes	Air quality regulation, climate regulation, water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination, natural hazard regulation
Cultural services	Benefits people gain through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences	Cultural diversity, spiritual and religious values, knowledge systems, educational values, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism

Table 1.1.3. Important environmental services provided by urban ecosystems (Bouland 1999).

	Street trees	Lawns/ parks	Urban Forest	Cultivated land	Wetlands	Streams	Lakes/ Sea
Air filtering	X	X	X	X	X		
Micro climate regulation	X	X	X	X	X	X	X
Noise reduction	X	X	X	X	X		
Rainwater drainage		X	X	X	X		
Sewage treatment					X		
Recreation/cultural values	X	X	X	X	X	X	X

to prevent nutrients and contaminants contained within the stormwater from reaching ground or surface waters (Herrmman 2012).

This is achieved through various physical, chemical and biological processes operating within them (Figure 1.1.1). This includes sedimentation, sulphate reducing bacteria and uptake by macrophytes respectively (Birch *et al.* 2004; Walker and Hurl 2002; Weis and Weis 2004; Sheoran and Sheoran 2006). The pathway of removal is influenced by the type of contaminant, the plant species present, and sediment characteristics, in addition to pH, volume of inflow and detention time (Nelson *et al.* 2006; Sheoran and Sheoran 2006; Birch *et al.* 2004; Nuttall *et al.* 1997).

There has been an increase in the number of artifical wetlands constructed for wastewater treatment over the last two decades and their use is now widespread in many countries, including Australia (Birch 2004; Herrmann 2012). They are seen as a low cost, low maintenance and environmentally friendly alternative to traditional mechanical and chemical wastewater treatments (Hammer 1989; Batty *et al.* 2005; Chen *et al.* 2006; Hadad *et al.* 2006; Ye *et al.* 2006).

Biodiversity support

As constructed wetlands are designed to behave as natural systems, in addition to providing effective and reliable wastewater treatment, they have the added dimension of providing a valuable habitat for wildlife (Figure 1.1.2). Given the magnitude of wetland habitat loss and fragmentation, these wetlands are often the only habitats supporting wildlife within an urban landscape (Hamer *et al.* 2011). This is especially important for organisms which are endangered due to the loss of natural wetlands. Constructed wetland habitats are important at local and global scales (Knight *et al.* 2003; Zhao and Song 2004; Batty *et al.* 2005; UNEP 2008; Herrmann 2012).

The biodiversity support function of constructed urban wetlands is likely to become increasingly important under the climate change scenario of an increasing frequency of extreme events, including floods and droughts. During dry seasons, and in times of drought, urban wetlands

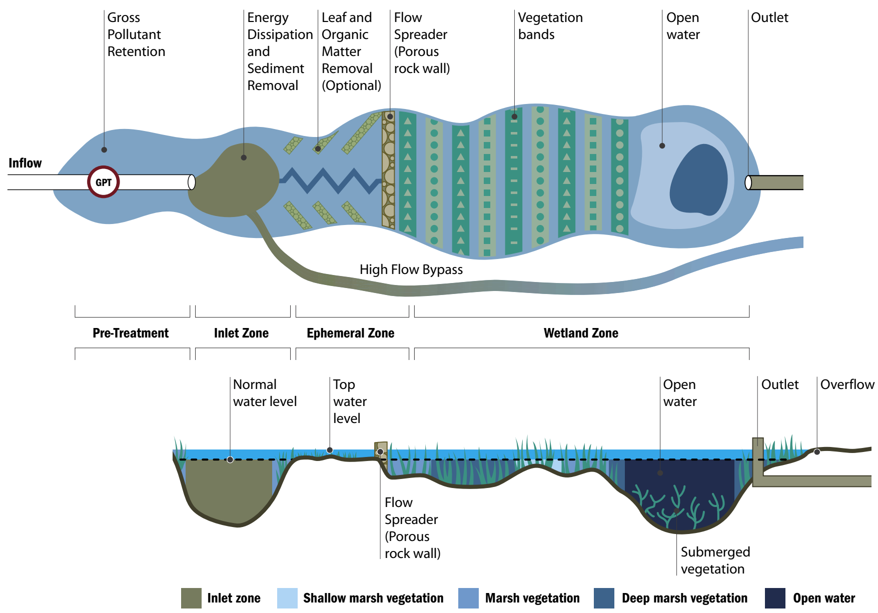

Figure 1.1.1. Schematic representation of a typical constructed wetland (adapted from Melbourne Water 2005). GPT = gross pollutant trap. OM = organic matter.

Figure 1.1.2. Urban wetlands provide habitat for many aquatic organisms including invertebrates, turtles and waterbirds.

and waterways will provide critical refugia for many aquatic species (both plants and animals). Studies in Melbourne and Perth have indicated that the significant investment in urban wetlands constructed for stormwater treatment and aesthetic amenity have added environmental benefits with respect to wetland biota, particularly waterbirds (Robson *et al.* 2013). We need to more fully determine the biodiversity values provided by constructed urban wetlands and understand the critical ecological processes supporting urban wetland ecosystems. This includes identifying the potential synergies and trade-offs between water treatment efficiencies and biodiversity values.

The importance of artificial urban wetlands for waterbirds is demonstrated by the Ramsar-listed Western Treatment Plant near Melbourne, in southeastern Australia. The Western Treatment Plant treats around 50% of Melbourne's sewage and generates almost 40 billion litres of recycled water a year (www.melbournewater.com.au). The treatment plant wetlands are an important resource for both permanent and migratory waterbirds, with over 270 species recorded (Murray and Hamilton 2010).

Freshwater turtles such as the eastern long-necked turtle (*Chelodina longicollis*) in southeastern Australia and the oblong turtle (*Chelodina oblongata*) in southwestern Australia, are able to use modified habitats such as golf course ponds, stormwater drainage lagoons and other urban water bodies. Turtles can grow faster, mature earlier and have higher fecundity in these modified environments than in less developed areas. However due to high road mortality and other human-induced vulnerabilities, populations may be limited to small areas of habitat (Giles *et al.* 2008; Roe *et al.* 2011). Furthermore, these wetlands become important refugia for amphibians when natural ponds have dried. These resources are especially important in a country such as Australia where the presence of permanent wetlands is often limited (Murray and Hamilton 2010; Hamer *et al.* 2011).

Within constructed wetlands, aquatic invertebrates play an important role in connecting the physico-chemical environment with higher taxa. Accordingly the presence of aquatic invertebrates is a good indicator of the ability of a wetland environment to support wildlife (Batty *et al.* 2005). The ability of wetland invertebrates to survive depends on the tolerance of individual species and the toxicity of in-flowing wastewaters. The biota is often restricted to organisms that are able to tolerate extremes of pH, elevated ionic concentrations and low dissolved oxygen. Constructed wetlands are usually dominated by tolerant species such as water boatmen (Corixidae), non-biting midges (Chironomidae), segmented worms (Oligochaeta) and roundworms (Nematoda) (Cheremisinoff 1995; Batty *et al.* 2005; Rawson *et al.* 2010). Some constructed wetlands contain species senstive to pollution, but usually only in very low numbers (Rawson *et al.* 2010). Invertebrate communities are more diverse where the toxicity of wastewaters is lower, such as near an outflow (Ye *et al.* 2004; Batty *et al.* 2005). The abundance of invertebrates is often lower in constructed wetlands than natural wetlands, even when water quality targets are met (Cheremisinoff 1995; Batty *et al.* 2005). This suggests that there are limitations on the biodiversity values supported by wetlands constructed for wastewater treatment.

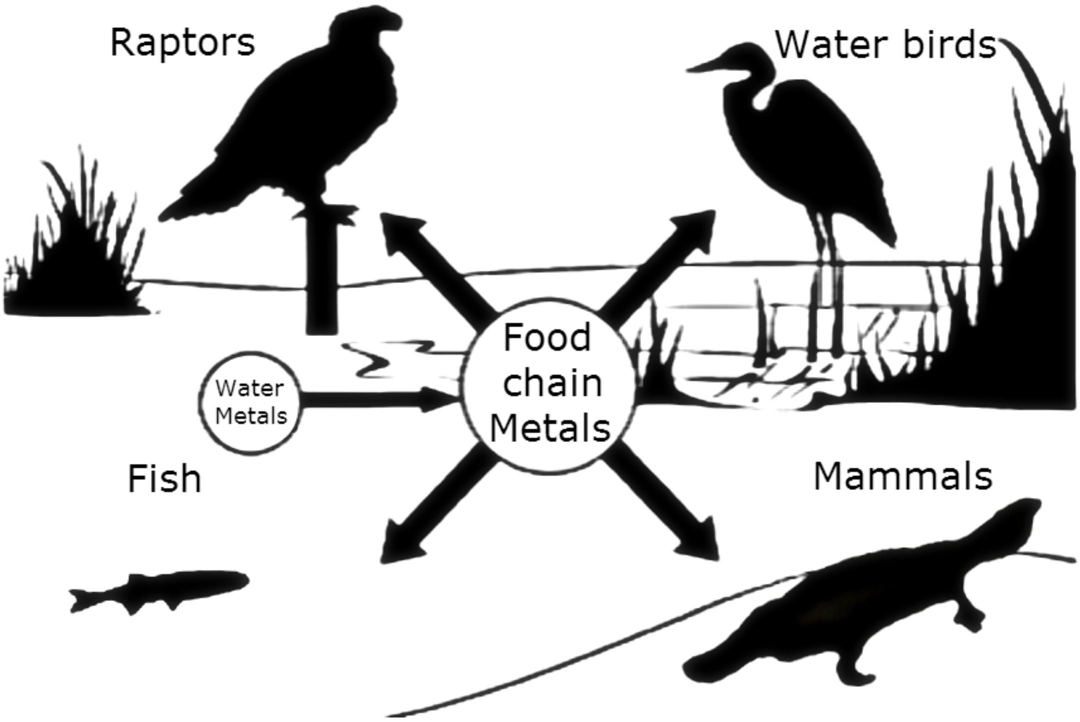

Figure 1.1.3. If metals become bioavailable they are potentially available for uptake by organisms which lead to bioaccumulation in the food chain (Lemly and Ohlendorf 2002).

Whether a constructed wetland is specifically designed to incorporate habitat for biodiversity or not, it is likely that wildlife will be attracted and there is a risk that organisms may be exposed to hazardous concentrations of pollutants within the system (Kadler and Knight 1996). If metals are available for uptake by aquatic invertebrates there is the possibility that bioaccumulation within the food web may occur (Figure 1.1.3) (Mays and Edwards 2001; Lemly and Ohlendorf 2002).

It is possible to design constructed wetlands to mitigate adverse impacts. Larger wetlands which incorporate areas of deep and open water are more able to sustain a diverse invertebrate community because the pH is often higher and concentrations of toxins are lower (Batty *et al.* 2005). Even pollutant sensitive taxa such as mayflies (Ephemeroptera) have been recorded in constructed wetlands with these habitat features (Batty *et al.* 2005).

An additional impact on macroinvertebrate communities in urban wetlands constructed on stream networks is the lack of good quality upstream habitat (Rawson *et al.* 2010). This can reduce the availability of organisms to colonise newly created wetlands (Herrmaan 2012). The diversity and cover of submerged and emergent vegetation is one of the most important factors in determining the diversity of macroinvertebrates within shallow aquatic systems. The area of the wetland and the size of the catchment are also important factors (Rawson *et al.* 2010; Herrmaan 2012).

Recreational use, landscape amenity and cultural values

World-wide, most conservation efforts are centred on large, biodiverse or relatively intact ecosystems and less attention is given to conserving urban environments (Chiesura 2004). Increasing urbanisation has been accompanied by a growing disconnection of city dwellers from nature. This detachment from the natural environment is considered to contribute to the depressive orders that are now the leading cause of disability in middle and high income countries (Keniger *et al.* 2013; White *et al.* 2013).

As more people move into towns and cities, the reliance on environmental interactions required for survival, such as hunting or fishing, has disappeared. Instead, people actively seek interactions with nature for enjoyment and recreation (Dallimer *et al.* 2012; Keniger *et al.* 2013). Cities are stressful places and so features, such as wetlands, which provide opportunities for interacting with the natural environment are often highly valued (Bouland 1999). This interaction is vital for health and wellbeing, with benefits for physical health, psychological wellbeing, cognitive ability and social cohesion (Dallimer *et al*. 2012; Keniger *et al*. 2013). Green spaces in the urban environment are able to provide aesthetic and cultural values to a city. Furthermore these environments are often the only opportunity that residents have to interact with 'nature' (Bouland 1999; Ehrenreld 2000).

The presence of natural assets such as wetlands, parks, forests and green belts contribute to quality of life and so it is important to provide urban populations with the opportunity to live next to, or close to, green spaces (Table 1.1.4) (Chiesura 2004; Keniger *et al*. 2013). Evidence is also emerging that interaction with nature during childhood may influence attitudes towards nature later in life, and that when children interact with nature there is a positive impact on self-esteem and mental well-being (Keniger *et al*. 2013).

Urban wetlands provide an opportunity for residents to access green spaces in towns and cities. Urban wetlands are often not only aesthetically

Table 1.1.4. The positive impacts on health and well-being provided by increasing the access of city dwellers to natural environments within urbanscapes (Keniger *et al*. 2013).

Benefit	Description	Examples
Psychological well-being	Positive effect on metal processes	• Increased self-esteem • Improved mood • Reduced anger/frustration • Reduced anxiety • Improved behaviour
Cognitive	Positive effect on cognitive metal processes	• Reduced mental fatigue • Improved academic performance • Education/learning opportunities • Improved ability to perform tasks • Improved cognitive function in children • Improved productivity
Physiological	Positive effect on physical function and/or physical health	• Stress reduction • Reduced blood pressure • Reduced headaches • Reduced mortality rates from circulatory disease • Faster healing • Addiction recovery • Perceived health/well-being • Reduced cardiovascular, respiratory disease and long-term illness • Reduced occurrence of illness
Social	Positive social effect at an individual, community or national scale	• Facilitated social interaction • Enables social empowerment • Reduced crime rates • Reduced violence • Enables interracial interaction • Social cohesion • Social support
Spiritual	Positive effect on individual religious pursuits or spiritual well being	• Increased inspiration • Increased spiritual well-being
Tangible	Material goods that an individual can accrue for wealth or possession	• Food supply • Money

pleasing, they also provide opportunities for activities such as bird watching. They provide local communities with the opportunity to see 'wild' species, which they may otherwise not encounter. Urban wetlands also provide a space for local residents to partake in recreational activities such as walking, running and dog walking.

Case Study: Urban wetlands in Melbourne

Historical

The peoples of the Kulin nation are the traditional owners of the land which is now known as Melbourne. Prior to European settlement there were extensive wetlands and swamps which were home to an abundant range of bird life. The largest wetland within Melbourne was the Carrum Carrum Swamp. This wetland was located on the eastern side of Port Philip Bay. It was 15 km in length, had a maximum width of 5km and covered an area of 4000 hectares.

As the population of Melbourne grew, pressure increased for the provision of housing, roads, water supply and waste disposal. Within 50 years of settlement there was no part of the wider Melbourne area that had not been developed in some way. The natural swamps and wetlands became seen as constraining and drainage of these habitats began. Not all of the swamps and wetlands were destroyed; some were kept for critical flood protection. This includes part of the Carrum Carrum Swamp which is today divided into two sections, known as Edithvale Wetland (101 ha) and Seaford Wetland (158 ha) respectively. In 2001 they were listed as Wetlands of International Importance under the Ramsar Convention. They are the largest remaining natural wetlands in the Port Phillip and Westernport basins (www.melbournewater.com.au; www.emelbourne.net.au).

Constructed wetlands

Many wetlands have been constructed on Melbourne stream networks primarily to protect water quality within the receiving waters of Port Phillip Bay (Figure 1). They also prevent flooding within local catchments, particularly where the increased imperviousness created by hard urban surfaces (roads and buildings) results in a flashy hydrology. As such these systems have been implemented to play a vital role in reducing

Figure 1. Stormwater treatment wetlands are built to reduce nutrient loads (especially nitrogen) entering Port Phillip Bay, Melbourne.

the environmental impacts of catchment urbanisation. In addition they provide important habitats for wildlife, provide local people with places for recreation and help people to be more aware of the environment around them (Melbourne Water 2010).

Management of Melbourne wetlands

Melbourne Water is responsible for the design and management of many of the constructed wetlands present within the greater Melbourne region. In addition, Melbourne Water manages the city's water supply catchments; treats and supplies drinking and recycled water; treats most of Melbourne's sewage; and manages waterways and major drainage systems in the Port Phillip and Westernport region (www.melbournewater.com.au).

Aesthetic, recreational and cultural objectives are all considered to be important in the design of Melbourne Water constructed wetlands. This includes retaining existing ecological and cultural values and mimicking as much as possible the physical characteristics of natural wetlands, including the structural and functional complexity of fringing, emergent and submerged vegetation. Planting native species ensures that the character of constructed wetlands is in keeping with the local surroundings. Provision is also made for recreational activities such as bird watching and picnicking. Wetland microhabitats are included in design criteria. These include the installation of rocks or logs to provide shelter and basking areas for native species (waterbirds and turtles). The planting of indigenous trees, shrubs and ground cover provides feeding and nesting sites for terrestrial and water birds. Additional habitats are provided where regionally or nationally significant species are known to occur. Separating faunal habitats from pollutant treatment areas adds to the biodiversity support role of constructed wetlands (Melbourne Water 2010).

Figure 2. Cherry Lake in Melbourne's southwest was a natural wetland prior to European settlement. Subsequently, it has been partly drained and modified due to pressure from urban development and is now in use as a retarding basin to protect the local community from flooding (Google Earth 2013).

Cherry Lake

Cherry Lake is a modified coastal wetland located in the south-western Melbourne suburb of Altona. The bayside suburb is 13 km from the central business district and is home to the largest chemical manufacturing industry in the southern hemisphere, the Altona refinery, and a car manufacturing plant. Cherry Lake covers an area of 60 ha within a larger reserve of 176 ha (Figure 2). Prior to European settlement, Cherry Lake was low-lying and seasonally flooded swampy land supplied by runoff from Cherry Creek and flood flows from Kororoit Creek. The water regime was highly variable and the wetland could be dry for periods greater than 12 months. As the surrounding area expanded and developed there was a greater demand to protect the local area against flooding. In 1963, parts of the swamp were drained by the Board of Works (now Melbourne Water). Levees were constructed and a concrete channel was built to carry flood flows out into Port Phillp Bay. Cherry Lake became an important flood retarding basin, in addition to being one of the most popular passive recreation facilities in the western suburbs (www.melbournewater.com.au).

Extensive reed beds dominated by Cumbungi (*Typha* spp) and Common Reed (*Phragmites australis*) that surround the lake provide examples of the areas remnant vegetation (www.dse.vic.gov.au). In addition to supporting waterbirds, including pelicans, swans and swamp hens, the site is also of important for the vulnerable Altona Skipper Butterfly (listed under the *Flora* and *Fauna Guarantee Act*). The butterfly feeds on Chaffy Saw Sedge (*Gahnia*) and this plant is considered to be vital for its survival (www.hobsonsbay.vic.gov.au).

A 3.5km walking and cycling trail surrounds Cherry Lake, allowing individuals and families, the opportunity to interact with nature through a variety of activities such as bird watching. The site is managed by Melbourne Water with support from a local volunteer group the 'Friends of Cherry Lake'. The group helps to care for the habitat around the lake. This includes managing and monitoring the *Gahnia* vegetation community which is important for the Altona Skipper Butterfly. Other management activities include removal of weeds including Boxthorn, Serrated Tussock and Spiny Rush, revegetation of weed infested areas with local native species and rabbit control (www.melbournewater.com.au).

Cherry Lake is an example of how a wetland system has been greatly altered from its original state due to the pressures created by urban development. Like many urban wetlands, the lake performs an important function, preventing flooding of the local community, while also providing valuable habitat for flora and fauna and providing local residents and tourist with the opportunity to interact with nature.

Figure 3. Despite being heavily modified, Cherry Lake provides important habitats for local wildlife.

Summary/ Conclusions

Wetlands are among the most productive habitats on earth and provide a number of essential ecosystem services, including provision of freshwater, food, fibre and biomass, biodiversity support, flood control, nutrient retention, microclimate modification and carbon sequestration. Despite being such a valuable resource they are under threat globally from diverse and multiple stressors, including urbanisation. Not only is the Earth's population increasing, but more people are living in cities than ever before, particularly in Australia.

Many original wetlands have been lost from urban areas as land has been developed to accommodate the housing and infrastructure needs of ever-expanding urban popluations. The highly imperviousness nature of urban catchments (the hard surfaces created by buildings, roads, foot paths and car parks) alters local hydrological regimes. The increasing concentrations of nutrients, metals and organic pollutants present in urban runoff degrades wetland water quality. Groundwater extraction for urban water supply threatens groundwater-dependent wetlands on sandy coastal plains, notably those on the Swan Coastal Plain, in southwestern Australia. Urban wetlands are also threatened by exotic and invasive species (both plants and animals), fragmentation and loss of connectivity. Urban wetlands are important for wildlife and are home to many animals that are dependent on the presence of permanent water. Perennial urban wetlands are extremely important because they provide aquatic refugia for many species during dry seasons and droughts. Urban wetlands also offer many recreational opportunities and have important aesthetic values. There is growing evidence that the green spaces, which urban wetlands represent, are an important way for communities to feel connected with nature. This connection reduces stress, crime rates and incidents of violence and increases psychological wellbeing.

Urban wetlands are important assets for the whole community. They provide essential ecosystem services, including biodiversity support and aesthetic, recreational and cultural values. Permanent urban wetlands can act as refugia for many species during dry periods and droughts. In an increasingly urbanised world, wetlands must be managed and valued for the important ecosystems that they are.

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