Keynote Lecture: The challenge of preserving biodiversity in urban and suburban environments — the Melbourne example

Mark J. McDonnell
Director, Australian Research Centre for Urban Ecology
Royal Botanic Gardens Melbourne, c/- School of Botany,
University of Melbourne, Parkville VIC 3010, Australia
markmc@unimelb.edu.au

ABSTRACT

The preservation, restoration and ecologically sound management of urban and suburban natural areas are crucial to the maintenance of global, regional and local biodiversity. Throughout the world the number and size of urban areas are increasing. It has been predicted that by the year 2025 over 60% of the world's population will be living in urban settlements. Unfortunately, our ecological understanding of the world has been obtained from studying natural areas specifically selected to minimize the presence of humans. In addition to their intrinsic value, urban and suburban natural areas are especially important for providing unique examples of pre-urbanized ecosystems at a local scale and are refugia for indigenous plants and animals. This makes them valuable sources of propagules and organisms for future restoration projects. Patches of indigenous vegetation located in cities and towns are also vital living laboratories for environmental education providing many urban dwellers their only opportunity to experience and learn about the region's natural heritage. Urban and suburban natural areas in Australia and throughout the world are facing many serious problems that threaten their persistence. The conservation, management and restoration of these valuable areas present a formidable challenge to Melbourne and other cities around the world.

This paper describes the current status of indigenous biodiversity in Melbourne and the future challenges we face in preserving our valuable natural resources.

INTRODUCTION

The preservation, restoration and ecologically sound management of urban biodiversity is crucial to the maintenance of global and regional biodiversity. Throughout the world the number and size of urban areas are increasing. It has been predicted that by the year 2025 more than 60% of the world's population will be living in urban settlements (World Resources Institute 1996). Unfortunately, our ecological understanding of the world has been obtained from studying natural areas specifically selected to minimize the presence of humans and thus we lack the information and tools to effectively maintain biodiversity and ecological processes in cities and towns.

The preservation of a diversity of indigenous plants and animals in cities and towns contributes to the quality of life of city dwellers. In addition to providing valuable ecosystem services such as cleaning the air, ameliorating climate and reducing impacts of potential pests and pathogens, to name a few (Daily et al. 1997; Bolund & Hunhammar 1999; Williams et al. 2001), it satisfies the human need to have contact with other organisms. This relationship between humans and nature is a serious topic of scientific study and has been referred to as 'biophilia' by E. O. Wilson (Wilson 1984; Kellert & Wilson 1993).

Typically, the preservation of biodiversity in urban environments requires the preservation of open space and remnant plant communities, but gardens, roadside and riparian strips can also provide valuable habitats for indigenous organisms (Scott et al. 2002). More work needs to be done to enhance the role of the 'matrix' of urban and suburban areas in preserving local biodiversity to supplement the loss of remnant patches in the landscape. Although patches of indigenous vegetation located in cities and

towns may not be considered of high regional conservation significance, they are vital living laboratories for environmental education providing many urban dwellers their only opportunity to experience and learn about the regions natural heritage.

The biodiversity of Australian and New Zealand cities and towns, and indeed the entire planet, is under threat due to a range of human activities including urbanization. The conservation, management and restoration of biodiversity present a formidable challenge to cities and towns around the world. This paper summarises the obvious and not so obvious threats to biodiversity in urban and suburban environments. Throughout the paper my research experiences in Melbourne, Australia are utilized to illustrate the impacts the growth and development of cities and towns can have on biodiversity.

THE MELBOURNE EXAMPLE

Melbourne was established in 1835 and has grown from 10 000 inhabitants in 1840 to more than 3 million residents today (Harvey 1982; State of Victoria 2002). In the 1960s, Melbourne covered some 97 851 ha, and by 1990 it had spread to cover over 202 600 ha in area. Much of this spread resulted in the conversion of farm land and remnant vegetation to suburban land use. Recent studies indicate that over the next 30 years Melbourne's population could increase by another 1 million people which equates to approximately 620 000 households over 30 years or 20 000 new households a year (State of Victoria 2002). Even though planning processes are being put in place to control this new growth, it will most likely be in the form of urban sprawl. The rapid urbanization of Melbourne has undoubtedly had a significant impact on the distribution and abundance of indigenous plants and animals in the area.

In 1998, the Australian Research Centre for Urban Ecology (ARCUE) was created as a division of the Royal Botanic Gardens Melbourne with the enlightened support of The Baker Foundation to increase our understanding of the ecology, conservation, restoration and management of biodiversity in cities and towns throughout Australia and the world. The mission of the Centre is to advance knowledge about biodiversity in populated areas, thereby aiding conservation and management of species and ecosystems in urban environments and enhancing the quality of life for people living in cities and towns. A comprehensive description of the activities of the Centre can be found on our website (http://arcue.botany.unimelb.edu.au/).

Over the past five years or more, the Centre's staff have been involved in a variety of projects including the:

1. Development of important bibliographic and GIS databases to document the biodiversity knowledge base of the greater Melbourne area (McDonnell et al.1999)
2. Initiation of much needed ecological studies of the ecology of urban plant and animal communities
3. Study of methods to regenerate and restore indigenous plant communities in urban environments (McDonnell & Williams 2000).

IMPACTS OF URBANISATION

As the density of humans increases during the building of cities and towns there are many changes to the surface of the land, the quality of the air, soil and water and the diversity of organisms (Young 2000). The process of urbanization invariably results in an increase in impermeable surfaces, the number of cars, energy use, pollution and the number of non-indigenous species, while concurrently resulting in the reduction of green space, indigenous species, remnant habitats and the reduction in the quality of the air, soil and water. The impacts of these alterations to the environment on biodiversity caused by urbanization are summarized in Table 1. The general impacts of air, soil and water pollution associated with urban development are fairly well documented in the literature (e.g., Freedman 1989; Graedel & Crutzen 1989; Paul & Meyer 2001). In this section I discuss in more detail the impacts on biodiversity associated with changes in disturbance regimes, heat island effects, light pollution, loss of native habitats, nitrogen deposition and non-indigenous species invasions.

Disturbance regimes

The important role disturbance regimes play in maintaining biodiversity and ecosystem processes was highlighted some 20 years ago (Pickett & White 1985). In Australia, one of the major influences on the composition and structure of indigenous plant and animal communities is the frequency and magnitude of fires (Bradstock et al. 2002). As areas become urbanized residents of cities and towns alter natural disturbance regimes by suppressing fire. This suppression of fire in grassland and heathland ecosystems has well documented detrimental effects on the composition and structure of plant communities. Indigenous plants that have adapted to fire regimes are commonly lost when fires are suppressed for long periods of time (e.g., >5 years) (Fox & Fox 1986; Lunt & Morgan 2002). Similarly, regular frequent prescribed burning which do not match the natural fire regimes can also reduce biodiversity in Australian eucalypt forests (Gill & Williams 1996). The suppression of fire in remnant grasslands and heathlands in the greater Melbourne area has reduced the number and abundance of several indigenous plants (Lunt & Morgan 1999; Phelan 2000).

Heat island effects

The creation of heat islands is becoming increasingly common in cities and towns across the globe (Landsberg 1981; Oke 1995). This effect manifests itself as warmer nocturnal temperatures in relationship to the cooler surrounding landscape. It occurs due to a set of complex interactions related to the increase in concrete and pavement used to build cities, generation of heat through wasted energy, and air pollution. Typically, the buildings and roads that make up cities store heat during the day and release this heat throughout the night resulting in temperature differences between the city centres and the surrounding landscape of between 1–2ºC (Landsberg 1981; Oke et al. 1999). This change in climate, although it appears small, can have a variety of impacts on organism and ecosystem processes. Higher temperatures could:

1. Reduce the risk of cold damage or death to organisms sensitive to cold temperatures
2. Alter the competitive interactions between organisms (e.g., favour non-indigenous species)
3. Alter the cycling of nutrients (McDonnell et al. 1997).

In Melbourne's inner city weather station it was common to have winter temperatures below 0ºC in winter between 1855 and 1984. Since 1985, this station has not recorded a single day with temperatures below 0ºC. In fact, the mean daily minimum temperature in July in the 1950s in Melbourne was approximately 3ºC, but by the late 1990s average minimum July

Table 1 Major impacts on biodiversity caused by the creation of cities and towns.

Impact	Effect
Air, Soil and Water Pollution	Loss of indigenous plants and animals
Change in disturbance regimes	Loss of indigenous plants and animals
Heat Island	Changes in local climate Alters the competitive interactions Encourages non-indigenous species
Light pollution	Loss of abundance and diversity of night flying insects
Loss of native habitat	Habitat destruction Landscape fragmentation Community sanitization
N-deposition	Alters competitive plant interactions encouraging the invasion of non-indigenous species
Non-indigenous species invasion	Loss of indigenous plants and animals

temperatures have risen to over 6ºC. This rise in winter minimum temperatures has been one of the contributing factors in the establishment of a new grey-headed flying-fox colony in Melbourne during the early 1980s (McDonnell unpublished data) and most likely has affected the current distribution of other indigenous and non-indigenous organisms in the area.

Light pollution

Although the effect of light pollution on astronomic observations is relatively well known (Riegel 1973), the impact of light pollution from cities and towns has only recently been identified as a major threat to biodiversity (Eisenbeis 2002, and pers. comm. 2003).

Night lights are especially threatening to populations of night flying insects such as moths, beetles and flies. These organisms are attracted to lights at night which typically results in their death. Studies of moth populations in Germany along a gradient of urbanization found that in the city centre there were only 120 species of moth while at the edge of town there were 650 species (Reichholf 1989). In addition to the loss of flying insects, light pollution has potential negative effects on plants, birds, frogs and many aquatic organisms. The direct loss of insects in urban environments due to excessive lighting could also have cascading ecosystem effects which may result in the loss of other species that feed on these organisms. There is a growing concern by astronomers, biologists, planners and policy makers about the effect of light pollution on a diversity of issues and thus groups have developed to reduce the amount of light pollution in cities and towns. Information on how to reduce light pollution is at the International Dark-Sky Association website (http://www.darksky.org/).

Loss of native habitats

Between 1986 and 1993, some 1600 km² of land was converted to suburban land use around Australia's five capital cities (Young 2000). The loss of habitat during the creation of cities and towns is one of the greatest threats to local indigenous biodiversity in urbanizing landscapes. In addition to the direct impacts of the destruction of indigenous habitat, there are several indirect impacts resulting from the fragmentation of the landscape. Typically, fragmentation results in an increase in edge environments and a decrease in interior habitats. It also increases the distance between similar habitats which could negatively impact the survival of small remnant populations of plants and animals. In urban and suburban environments, even when entire habitats are not destroyed, components of them can be significantly altered. For example, because of societal pressure for clean and tidy living environments homeowners and park managers tend to sanitize natural remnant patches of vegetation usually resulting in the removal of the ground layer of litter and plants, and any dead or dying plants in the area. These practices reduce the availability of nesting and food resources for many animals and insects.

An analysis of the remnant vegetation in the greater Melbourne area has revealed the significant loss of remnant patches of vegetation during the creation of the city (Fig. 1). In the inner city of Melbourne only 1.66% of the area still remains in remnant vegetation while in the outer suburbs nearly 16% of the area is still covered with remnant vegetation. Because most of this land is in private ownership it too will be threatened by suburban development as the city grows in the future. A breakdown by broad vegetation categories of the amount of remnant vegetation that is still present in Melbourne is presented in Table 2. In the outer suburbs patches of forest, heath and riparian vegetation comprise the largest areas of remnant vegetation while in inner Melbourne forest, grassy woodlands and riparian vegetation are the most abundant. In the inner city the average size of a remnant patch of vegetation is only 1.43 ha while in the outer suburbs it increases to 6.76 ha. A recent study (Van der Ree 2004) revealed that the creation of Melbourne has resulted in the loss of approximately one-third of the mammal species known to occur in the area. Most of the animals that became locally extinct were small ground dwelling mammals.

N-deposition

Due primarily to the burning of fossil fuels, especially through the use of automobiles, approximately three times as much nitrogen

in the form of nitrogen oxides and gaseous ammonia are released into the atmosphere than occurs through natural processes. As a result, NO_2 concentrations are commonly 5–10 times higher in urban than in rural areas (Bytnerowicz et al. 1987; Hanson et al. 1989). In the Melbourne airshed, it is estimated that for the reporting year 2002–2003 some 91 000 000 kg (91 000 tonnes) of oxides of nitrogen were released into the atmosphere (National Pollution Inventory 2002–2003). In addition to contributing to the creation of smog, some of this nitrogen is deposited back down to the ground in the form of both wet and dry deposition. In many industrial areas around the world, especially eastern North America and Central Europe, this anthropogenic input of nitrogen contributes to acidification of the soil and the acidification and eutrophication of lakes and streams. Although the levels of nitrogen deposition in Australia do not result in an acid rain problem, the increased nitrogen in and around cities could result in the fertilization of the soil as well as lakes and streams. The increased nitrogen inputs can significantly affect many soil-plant and plant-plant interactions (Jeffries & Maron 1997). Because Australian soils are relatively nutrient poor, addition of any fertilizers has the potential of increasing the competitive advantage of non-indigenous plants over indigenous species (Clements 1983).

Non-indigenous species invasions

One of the biggest threats to natural ecosystems around the world is the invasion of non-native species (Adair & Groves 1998). It is an especially acute problem in urban areas due to the abundance of introduced plants and animals. In Australia, it is estimated that there are more than 2000 non-native naturalised plants accounting for nearly 15% of the total flora. In the state of Victoria, some 28% of the flora is composed of non-indigenous plants which either completely or predominantly make up over 65% of the vegetation cover. Although the number of naturalised non-native animals is much smaller than plants in Australia, animals such as rabbits, cats, foxes and dogs have had significant negative impacts on native species of plants and animals. Due to the propensity of humans to grow exotic garden plants and to have pets, urban areas will always be exposed to the invasion of non-indigenous species and will typically be the source of invasions into the surrounding landscape. Furthermore, the activities of humans facilitate the spread of these species (Hobbs & Humphries 1995). MacDonald et al. (1989) studied several North American nature reserves and found a direct positive correlation between the number of exotic plants present and the number of visitors per year. They suggest that this increase in non-indigenous species is the result of the introduction of non-indigenous plant propagules by the visitors or their vehicles, and an increase in human disturbances resulting in habitat modifications. Both natural and human induced disturbance of indigenous plant and animal communities can result in reduced competition for the invader as well as increased resource availability, each of

Table 2 The amount of remnant vegetation remaining in the Greater Melbourne Area separated by inner city and outer suburbs (see Fig. 1 for more detail).

Broad Vegetation Category	Outer Suburbs		Inner City	
	No. of Patches	Area (ha)	No. of Patches	Area (ha)
Coastal	369	2347	10	10
Forest	7036	61 897	112	230
Grassland	83	3949	49	46
Grassy Woodland	1731	7829	106	239
Heath	1550	10 516	120	114
Riparian	1447	6822	138	257
Wetland	2145	4503	104	43
Miscellaneous	182	587	47	41
Total	**14 543**	**98 450**	**686**	**980**

which would favour the successful establishment of non-indigenous species.

CONCLUSION

Maintaining biodiversity in cities and towns is critical to both the ecology of the region and also the health and well-being of the human inhabitants. The creation of urban and suburban landscapes typically results in the significant loss of indigenous plant and animal communities. Although many indigenous animals and plants still persist in these human dominated areas, methodologies need to be developed to supplement the loss of remnant habitats with the creation of native plantings in the urban matrix. Similarly, land managers and the public must be educated about the need to leave plant litter and branches on the ground as well as standing dead trees, and not sanitize the landscape so as to provide habitat for many species of mammals and birds. The continued existence of a diversity of organisms in urban and suburban environments is the result a complex set of ecological, physical and social interactions. In order to maintain biodiversity in cities and towns in the future we must create:

1. A solid ecological, social and physical knowledge-base on urban environments
2. Ecologically sound conservation and management practices
3. Far reaching environmental education programs
4. Ecologically based policies.

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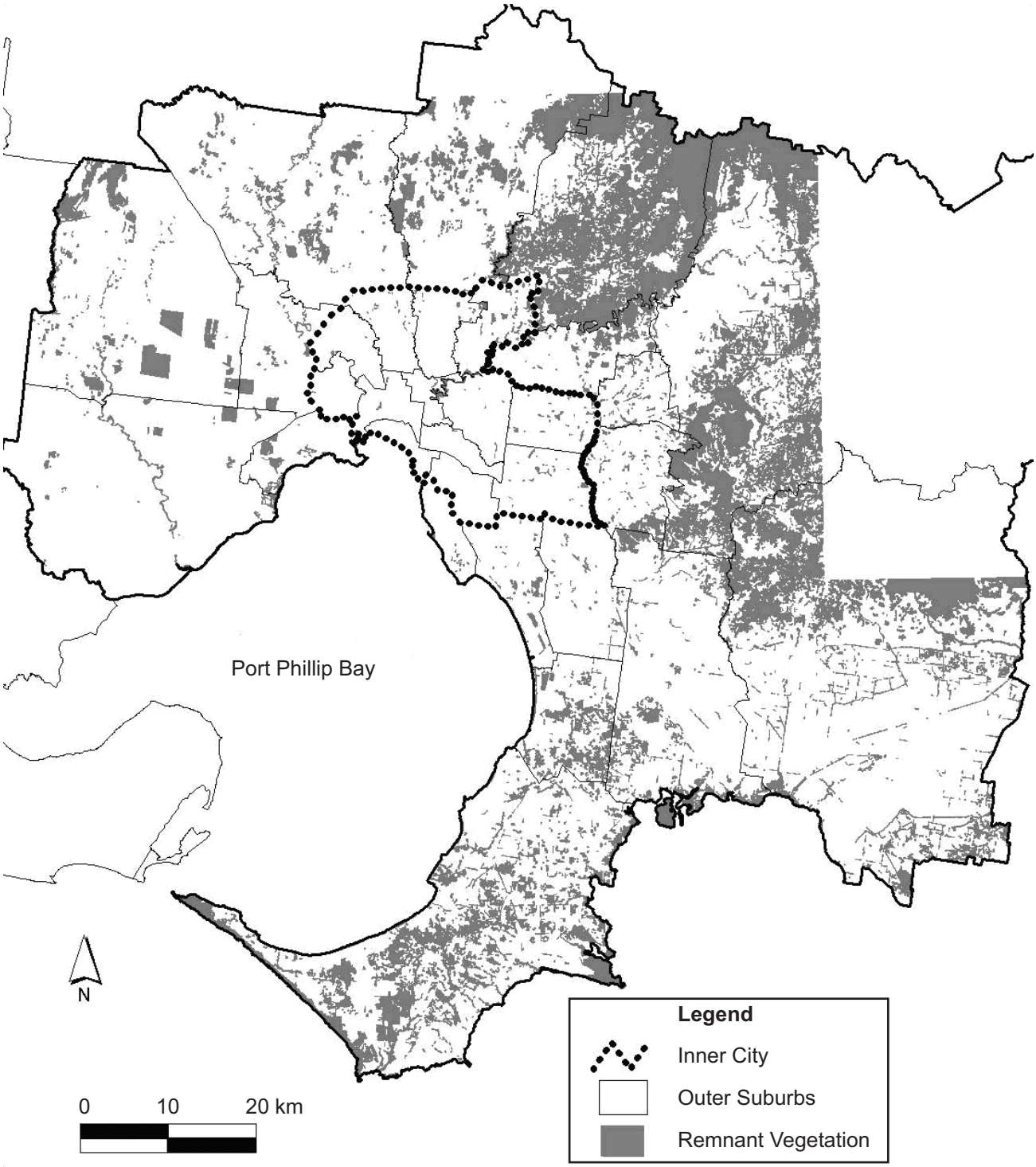

Fig. 1 Distribution of remnant vegetation in the greater Melbourne area, Australia. The area within the dotted line is considered inner city; everything outside is referred to as the outer suburbs. Map created by the Australian Research Centre for Urban Ecology and the Victorian Department of Sustainability and Environment.