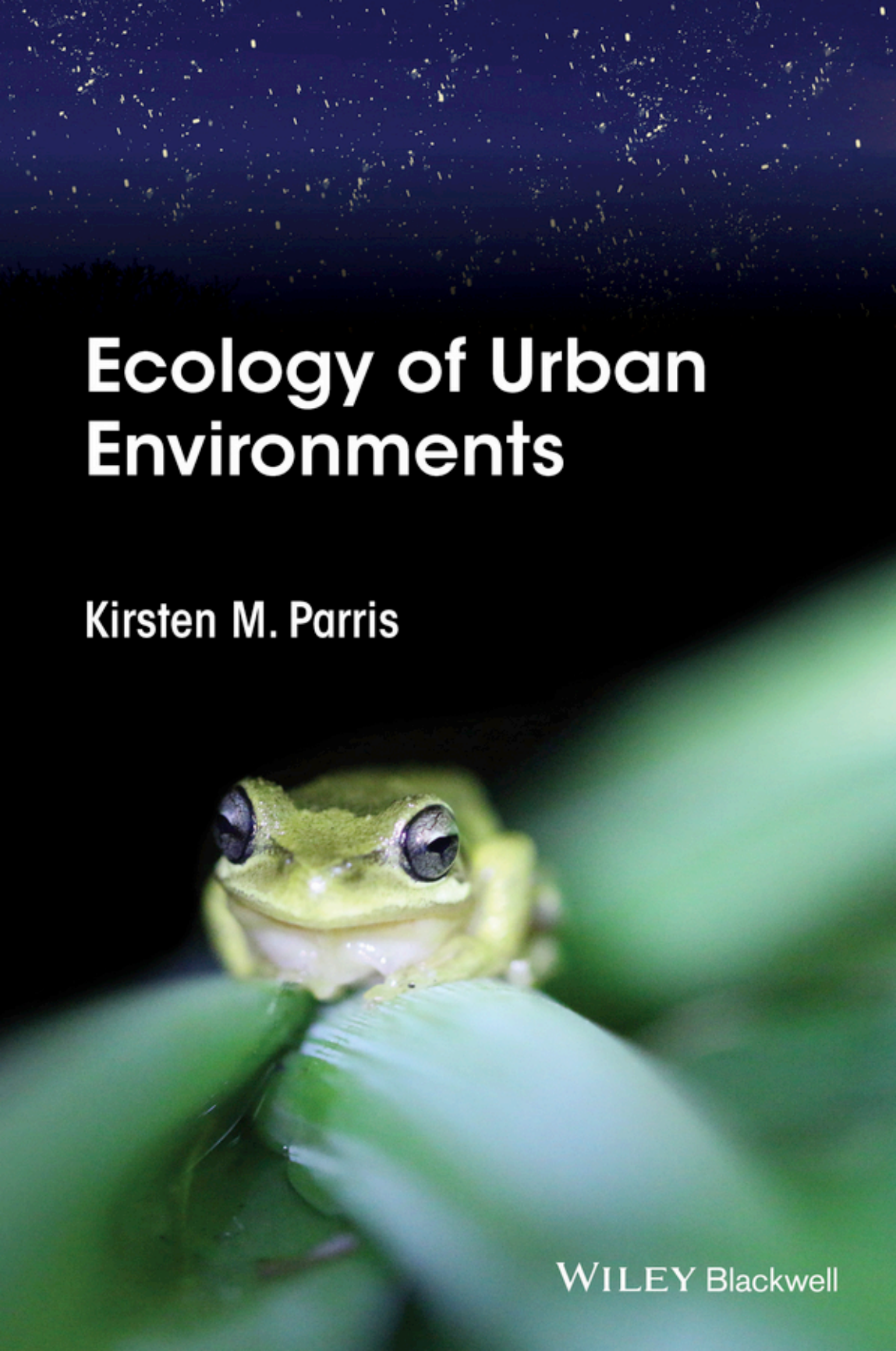
Ecology of Urban Environments

Kirsten M. Parris



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For Mick and Owen, my biggest supporters

and

In memory of Joanne Ainley, urban ecologist

Contents

Foreword

In the first quarter of the 21st century, we are living in a unique time in history – we are witnessing the move to the Anthropocene, a geological period in which humans have become a major driver of planetary processes. This time has also been termed the "Great Acceleration", a period of rapid increase in a large array of human activities with correspondingly large impacts on many environmental and biological processes. One of the clearest indicators of the changes underway is the emergence of the city as the main human habitat. For most of human history, the majority of the human population lived in rural or extensive landscapes, with only a few settlements that could be called "cities". Rapid human-population increase and industrialization from the 1800s onwards has been paralleled by a dramatic increase in the number and size of cities and an ever-increasing proportion of the human population living in urban areas. For the first time in history, humans are predominantly an urban species.

Cities are therefore extremely important environments from a human perspective: they are where most people now live. They form the centres of economic and cultural activity and are as diverse as the economies and cultures that created them. Cities come in all shapes and sizes, some developing from early hubs of trade and navigation and some springing up in entirely new locations. Early cities tended to be compact and geared for travel by foot or horse. However, cheap cars and mass transit have released cities from their earlier spatial constraints and many now sprawl extensively in all directions. Planning and management of urban form and function have become increasingly important endeavours as cities evolve, grow and require more efficient and effective private buildings, public spaces and essential services.

Cities are not only home to humans, however. Most cities are mosaics of built infrastructure and open space – parks, gardens, waterways and remnants of the nature that was present prior to the city's construction. These spaces are inhabited by a wide range of species, some of which thrive in the urban environment and some of which struggle. The mix of species present can include many species native to the region and many that have been introduced or have adapted themselves to the urban environment. Just as the city provides a focus for human creativity, it can also act as a place where new biologies play out – new combinations of species, species doing new things, and species interacting in novel ways with humans and their built environment.

Given the increasing importance of the city environment and the richness and fascination of the biological systems that develop in cities, it might seem odd that the field of urban ecology has only blossomed quite recently. Indeed, a few decades ago, it would appear that cities were not regarded as places where ecologists would

want to work – seeking out instead the remote, apparently untouched areas where the ecology was "intact". Today, cities are seen more as one end of a spectrum of humanized landscapes and are increasingly the subject of research into their ecological function. How do all the species found in cities persist and thrive? How do ecological communities develop within the altered environments found in cities? How does the urban ecosystem "work" with respect to flows of water, nutrients and energy? How do humans relate to, modify, and live in these environments? And, finally, are there better ways to plan and manage cities and their components that lead to greater liveability for humans and diverse biological communities alike?

This is the stuff of urban ecology, a growing field that seeks to understand how cities work in terms of their ecology and in relation to both their human and non-human inhabitants. This book is, a very timely contribution that provides an accessible yet fascinating synthesis of the ecology of urban environments. Within a strong framework of existing ecological theory, it explores how the construction and expansion of cities influence the characteristics of urban environments and the dynamics of populations, communities and ecosystems. It considers the ecology of human populations in cities, and presents a compelling case for conserving biodiversity and maintaining ecosystem services in urban landscapes. Overall, it seeks to help us better understand, plan and manage our primary habitat – a task that gets more pressing and important by the minute, both for ourselves and for the other species with which we share our cities.

Richard J. Hobbs
University of Western Australia

Preface

A long time ago came a man on a track
Walking thirty miles with a sack on his back
And he put down his load where he thought it was the best
Made a home in the wilderness

He built a cabin and a winter store
And he ploughed up the ground by the cold lake shore
The other travellers came walking down the track
And they never went further, no, they never went back

Then came the churches, then came the schools
Then came the lawyers, then came the rules
Then came the trains and the trucks with their loads
And the dirty old track was the Telegraph Road

Then came the mines, then came the ore
Then there was the hard times, then there was a war
Telegraph sang a song about the world outside
Telegraph Road got so deep and so wide
Like a rolling river

And my radio says tonight it's gonna freeze
People driving home from the factories
There's six lanes of traffic
Three lanes moving slow

I used to like to go to work but they shut it down
I got a right to go to work but there's no work here to be found
Yes, and they say we're gonna have to pay what's owed
We're gonna have to reap from some seed that's been sowed

And the birds up on the wires and the telegraph poles
They can always fly away from this rain and this cold
You can hear them singing out their telegraph code
All the way down the Telegraph Road

Mark Knopfler,
Telegraph Road

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CHAPTER 1
Introduction

1.1 Setting the scene

Reading this book, there is a good chance that you live in an urban environment – a town or a city. And if you look out of your window or door, you might see buildings, roads, cars, fences and street lights, as well as people, cats, dogs, trees or flowers. You might hear a train rumbling, a jackhammer hammering, a violin playing, children laughing or birds singing. You might smell diesel exhaust from a passing truck, risotto cooking at a nearby restaurant, newly-mown grass from the park across the road, or the stench of a rubbish heap or an open drain. These are the contrasts of life in the city, where the best and worst of human existence can be found, and where habitats constructed for people can complement or obliterate the habitats of other species. Ecologists strive to understand the processes of and patterns in the natural world. Until recently, many ecologists practised their science in places far from cities, considering human activity to be a disruption – rather than a part – of nature. But ecological principles apply in urban environments too, and the separation of humans from the rest of nature occurs to our detriment. Urban ecology is a relevant and valuable discipline in the highly-urbanized world of the 21st century.

1.2 What is urban ecology?

As a natural science within the broader discipline of biology, ecology is the study of the distribution, abundance and behaviour of organisms, their interactions with each other and with their environment. Ecology traverses many scales, from within individual organisms to whole individuals, populations, communities and ecosystems. Organisms are living things, such as bacteria, fungi, plants and animals. Human animals (people) have not generally been studied alongside other organisms as part of ecology (but see human behavioural ecology: Winterhalder and Smith 2000; Borgerhoff Mulder and Schacht 2012). This is the first point of difference between urban ecology and other ecological disciplines; the second is its focus on urban environments, which can be considered as habitats designed by people for people.

In this book, I define urban ecology as the ecology of all organisms – including humans – in urban environments, as well as environments that are impacted by

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the construction, expansion and operation of cities, such as forested watersheds (catchments) that supply drinking water to urban populations. Urban ecology includes people because the presence, population dynamics and behaviour of people, and the environmental changes that occur when they construct towns and cities, are central to our understanding of how urban systems function. Urban ecology has a different meaning in the social sciences, where it describes an approach to urban sociology that uses ecological theory to understand the structure and function of cities (e.g., Park and Burgess 1967). Some authors also use the term urban ecology to describe an interdisciplinary field that brings together the natural sciences, social sciences and humanities (e.g., Dooling et al. 2007; see Chapter 8 for further discussion of this point). However, the motivation for and focus of this book are strongly grounded in the natural science of ecology. Ecology has much to offer the study of cities and towns, and this book provides a conceptual synthesis of the extensive but often disparate urban-ecological literature. In combination with other disciplines in the natural sciences, social sciences and humanities, an improved understanding of urban ecology will make a vital contribution to improved urban planning, design and management, for the benefit of all species that live in cities.

Urban ecology is a relatively young discipline and there has been some debate about what it should encompass and how the term "urban" should be defined (e.g., Collins et al. 2000; McIntyre et al. 2000; Pickett et al. 2001). For example, should we recognize an urban area by the number or density of people living there, by certain characteristic landscape patterns, by the density of features such as buildings and roads, or a combination of these things (McIntyre et al. 2000; Luck and Wu 2002; Hahs and McDonnell 2006)? Is there a single definition of urban that everybody should use, or are there a number of acceptable definitions that are suitable for different research questions? Wittig (2009) supports a very narrow definition of the term urban, as inner-city neighbourhoods dominated by concrete, asphalt and buildings, with no original vegetation remaining. This excludes other parts of cities, such as streams, private gardens and areas of remnant vegetation. It also excludes environments outside towns and cities that are nonetheless impacted by them. Pursuit of one definition of "urban" to be used in all urban-ecological studies may not be very useful, as definitions are likely to change with the scale of a study and the questions being asked. What is urban for a stream or an owl may differ from what is urban for a person, a beetle or a fungus. However, it is important that the definition is both clear and quantitative to allow the methods of a study to be replicated, and to assist comparison between studies and formal meta-analysis (McIntyre et al. 2000).

1.3 Why is urban ecology interesting?

Urban ecology is interesting for at least five reasons: (i) urban environments are extensive and growing; (ii) their ecology is inherently interesting; (iii) they are ideal for testing and developing ecological theory; (iv) the nature of urban

environments affects the health and wellbeing of their human inhabitants and (v) they are important for conserving biological diversity. An improved understanding of urban ecology will not only advance the discipline of ecology as a whole, it will help us to save species from extinction, maintain ecosystem functions and services, and improve human health and wellbeing. Particularly in these times of rapid human-population growth and urbanization, a better understanding of urban environments will help us to create more liveable cities that provide high-quality habitat for humans and non-humans alike. I address each of these points in more detail below.

1.3.1 Urban environments are extensive and growing

For the first time in history, more than half the world's human population lives in urban areas. The number of people living in cities has risen dramatically since the industrial revolution, as opportunities for employment have expanded in urban areas and the demand for agricultural labour has declined with increasing mechanization. The United Nations Population Fund (UNFPA) estimates that the world's current urban population of 3.9 billion people will expand to 4.9 billion by 2030 and 6.4 billion by 2050 (Figure 1.1a), compared to an urban population of just 220 million at the beginning of the 20th century (UNFPA 2007; UN 2014). This equates to a 22-fold increase in only 130 years. Urban areas in the developed world will grow slightly, while much of the expected increase in the number of people living in towns and cities will occur in developing countries in Africa, Asia, Latin America and the Caribbean (Fig 1.1b; UNFPA 2007). The social and environmental implications of the shift to urban living are profound, but they also vary dramatically between regions.

Urban expansion in developed countries such as Australia and the USA is typically accommodated through the construction of houses on individual blocks of land on the outskirts of towns and cities (Figure 1.2). Most houses are inhabited by a single family, and have electricity, potable tap water, one or more bathrooms connected to a closed sewage system, a telephone and a sealed road at their front door. Some houses have swimming pools; many have air-conditioners. Relatively large areas of land accommodate only a few people, and the resulting expansion of cities across the landscape is known as urban sprawl (Soule 2006). In contrast, many people moving to urban areas in sub-Saharan Africa, Latin America, India and China are accommodated in informal settlements (also known as slums or shanty towns) within or on the edges of cities (UNFPA 2007). These are characterized by a high density of people living in makeshift dwellings with poor sanitation, little or no access to clean drinking water, and uncertain tenure (Figure 1.3). Hundreds of people may share a single bathroom; water used for drinking can be contaminated with human waste; dwellings often have no electricity or ventilation; and there are no paved roads or facilities for waste disposal (Geyer et al. 2005; UNFPA 2007). Informal settlements are frequently built in areas subject to natural disasters, such as floods and landslides, and because the people who live there have no contractual right to do so, their dwellings can be demolished at short notice (Hardoy and

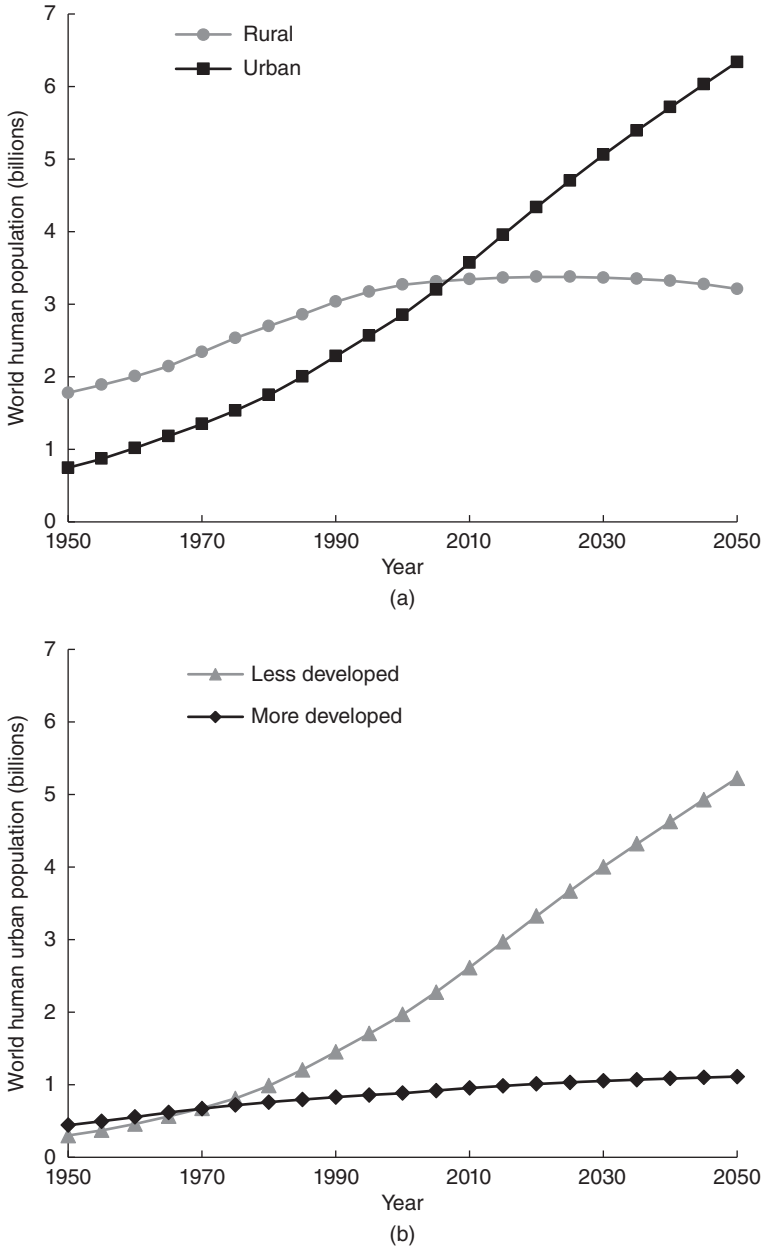

Figure 1.1 (a) World population of humans in urban and rural areas and (b) the urban population of humans in less developed and more developed regions of the world, 1950–2050. Data from United Nations, Department of Economic and Social Affairs, Population Division (2014).

Figure 1.2 An ordered suburb in Las Vegas, Nevada, USA. Picture has been straightened, cropped and converted to black and white. Photograph by ulybug. Used under CC-BY-2.0. https://creativecommons.org/licenses/by/2.0/.

Figure 1.3 Houses in the Kibera Slum, Nairobi, Kenya. Picture has been cropped and converted to black and white. Photograph by Colin Crowley. Used under CC-BY-2.0 https://creativecommons.org/licenses/by/2.0/.

Satterthwaite 1989; Tibaijuka 2005; Padhi 2007). An estimated 1 billion people, or one-sixth of the world's population, were living in informal settlements in 2005 (UN-Habitat 2006).

Other styles of urban development fall between these two extremes. Medium- and high-density townhouses and apartments are features of urban living in many parts of the world, providing a high standard of living with modern facilities and infrastructure but occupying less space than detached houses. Each type of urban expansion affects the biological diversity and ecosystem function of the newly-urbanized areas, and other associated habitats, in very different ways (Liu et al. 2003). For example, the materials and energy used to construct large, low-density houses on the outskirts of an Australian city and to maintain the lifestyle of their inhabitants are many times greater than those used by the inhabitants of a shantytown in South Africa or Bangladesh (Wackernagel and Rees 1996; McGranahan and Satterthwaite 2003). The health and wellbeing of the people living in each type of urban neighbourhood also varies dramatically (see later in this chapter for further discussion of this point). Therefore, we cannot think of urbanization (the construction of towns and cities) or urban expansion (an increase in the human population of cities) as uniform processes. In the coming decades, urban expansion in the developing world will present enormous ecological and social challenges. I argue that these challenges will be better met with an improved understanding of urban ecology.

1.3.2 Urban environments have inherent ecological interest

Urban environments are of intrinsic ecological interest, partly because they can be so different from the habitats they replace. How do ecosystems, communities, species and populations adapt to the dramatic changes associated with the conversion of wild or agricultural land into habitat for people? Which species and communities thrive and which suffer? Do novel biological communities arise when native species are lost and exotic species invade? If so, are these communities functionally similar to the ones they replace, even though they are compositionally different? Can urban areas function as urban ecosystems? Is there a particular level of urbanization at which ecosystem function breaks down? What are the relationships between human preferences and actions and the conservation of biological diversity in cities? And how is human health influenced by air pollution, tree cover or access to open space? We know the answers to some of these questions for some parts of the world, but there are many more relationships between non-human organisms, humans and their environment in cities to be further explored.

1.3.3 Urban environments are ideal for testing and developing ecological theory

Much ecological theory has been developed to explain the distribution, diversity, behaviour and interactions of organisms in relatively pristine habitats away from human disturbance. Examples include the theory of the ecological niche

(Hutchinson 1957), interspecific competition (Tansley 1917; Connell 1961), optimal foraging theory (Charnov 1976), predator-prey relations (Volterra 1926; Lotka 1932), the equilibrium theory of island biogeography (MacArthur and Wilson 1963, 1967), metapopulation theory and patch dynamics (Levins 1969; Pickett and White 1985), food webs (Hairston et al. 1960; Murdoch 1966), metacommunity theory (Gilpin and Hanski 1991; Leibold et al. 2004) and the neutral theory of biodiversity and biogeography (Hubbell 2001). Behavioural theories such as game theory (Maynard Smith and Price 1973) and those pertaining to animal communication, mate choice and sexual selection (e.g., Zahavi 1975; Marten and Marler 1977; Wells 1977; Kirkpatrick and Ryan 1991) have also been developed largely without reference to the behaviour of animals in urban settings.

As argued by Collins et al. (2000), any worthwhile ecological theory should apply to urban as well as rural or wild environments. Theories that have been put to the urban test, such as optimal foraging theory (Shochat et al. 2004), niche theory (Parris and Hazell 2005), the intermediate disturbance hypothesis (Blair and Launer 1997), metacommunity theory (Parris 2006), diversity–productivity relationships (Shochat et al. 2006) and food webs/trophic dynamics (Faeth et al. 2005), have all fared well. This suggests that much – if not all – existing ecological theory is applicable to urban areas. The dynamic nature of urban environments may also encourage the development of new ecological theory, as well as new ways to integrate ecological, social and economic theories to understand better the ecology of urban systems.

1.3.4 The nature of urban environments affects human health and wellbeing

The nature of our surroundings affects human health and wellbeing in obvious and subtle ways. In urban areas, the starkest contrast in health and wellbeing is between people living in secure, well-constructed housing and those who are homeless or living in informal settlements. Inadequate sanitation, limited access to clean drinking water and poor protection from extremes of weather dramatically increase the risk of disease in slum communities, while a lack of privacy and security exposes women to violence and sexually-transmitted infections such as HIV-AIDS (Amuyunzu-Nyamongo et al. 2007; UNFPA 2007). But characteristics of the urban environment also affect the health of the adequately-housed urban dweller. Access to green nature and open space in cities provides opportunities to exercise and improves mental health (Giles-Corti et al. 2005; Gidlöf-Gunnarsson and Öhrström 2007). Recent research has shown that urban sprawl is correlated with increased rates of obesity and an increased risk of traffic and pedestrian fatalities (Ewing et al. 2003, 2006, 2016; Smith et al. 2008; Mackenbach et al. 2014). Sprawling neighbourhoods often have few footpaths, and facilities such as schools and shops are separated from residential areas. As a consequence, residents are more likely to drive their cars than to walk or cycle (Ewing et al. 2016).