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Introduction: Scope of the book and need for developing a comparative approach to the ecological study of cities and towns

MARK J. MCDONNELL, JÜRGEN H. BREUSTE AND AMY K. HAHS

Introduction

The growth of cities and towns together with the associated increase in their ecological 'footprint' is one of the most serious ecological problems facing the world today. The increase in the number of people living in cities and towns, coupled with the magnitude and intensity of human activities, has resulted in what Likens (1991) refers to as human-accelerated environmental change. This includes changes in land use, toxification of the biosphere, invasion of exotic species and loss of biotic diversity. These changes are most evident in major cities, but significant changes are also occurring in peri-urban areas, in small towns and especially in coastal settlements. The rate of change associated with the expansion and creation of cities and towns is particularly high in developing countries (Lee, 2007). Human-accelerated environmental change is occurring at small and large spatial scales throughout the world, but the true magnitude of the impact of these changes is difficult to envisage because of uncertainties in the predicted effects of global climate change (IPCC, 2001).

We face many challenges and potential conflicts if we are to manage current day-to-day problems and attempt the bigger task of creating sustainable cities and towns in the future. Although cities and towns are dominated by human-built structures and activities (buildings, vehicles, impermeable surfaces, parks,

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etc.), they are functioning ecosystems that possess many of the same components (plants, animals, water, soil, etc.) and processes (i.e. nutrient and water cycling) as less human-dominated natural systems (McDonnell and Pickett, 1993b; Grimm *et al.*, 2003). If we are to succeed in creating sustainable cities and towns, we need a more comprehensive understanding of how these ecosystems are structured and how they function. It is equally important that everyone associated with human-dominated environments, including planners, builders, economists, policy makers, academics and the public, use this understanding when making decisions that affect the physical, socio-economic and ecological vigour of these ecosystems (Nilon *et al.*, 2003). Attempts have been made to incorporate ecological principles into urban planning but more efforts will be needed (Sukopp *et al.*, 1995; Niemelä, 1999a; Felson and Pickett, 2005).

Historically, there has been a plethora of information available on the physical and socio-economic condition of cities and towns. Unfortunately, our current ecological understanding of cities and towns is poor by comparison because traditional ecological studies, especially in the New World and Oceania, have focused on areas with low human population densities (McDonnell and Pickett, 1993b). Over the past 20 years there has been a growing body of research on the ecology of cities and towns (Gilbert, 1989; Sukopp *et al.*, 1990; McDonnell and Pickett, 1993b; Breuste *et al.*, 1998; Pickett *et al.*, 2001; Paul and Meyer, 2001; Sukopp, 2002), but the demand for additional information and for the development of 'general principles' by policy makers, management and public stakeholders has been difficult to fulfil with the available state of our knowledge.

The bulk of our current understanding comes from research that can be described as 'ecology in cities' (Grimm *et al.*, 2000). These studies are focused on the effect of human settlements on populations, communities and ecosystems and, for example, would involve the study of the distribution and abundance of native and exotic organisms within a city or the rate of decomposition within remnant patches of vegetation in a city versus patches outside a city. Relatively few studies have focused on the 'ecology of cities', which involves developing an integrated understanding of the ecology of the collective parts of cities and towns (Grimm *et al.*, 2000). These studies would involve assessments of the flux of nutrients, water, energy and organisms throughout entire cities and towns (Newcombe *et al.*, 1978), or the effects of land-use change over time on the distribution and abundance of organisms within a city (Wu *et al.*, 2003). It seems reasonable to deduce that the most appropriate and productive questions that can be addressed using this integrated approach are at the scale of whole cities and towns. Focusing research questions at this scale requires multidisciplinary teams of researchers and large amounts of resources (time, money and energy) that are difficult for individual research groups to acquire, and thus,

understandably, relatively little progress has been made. The result is that there have been few basic ecological studies focused on the ecology 'of' cities.

Over the past five years there has been a growing call to integrate the physical, biological/ecological and social components of urban environments in order to develop a holistic ecology of urban areas which has been identified as the crucial first step in creating sustainable cities (Collins *et al.*, 2000; Grimm *et al.*, 2000; Pickett *et al.*, 2001; Alberti *et al.*, 2003). Historically, ecologists have been criticised for using very coarse measures to represent the human and economic components of urban ecosystems. However, in many cases we are still trying to understand even these coarse-scale ecological patterns. To some extent, the level of integration between the social, physical and ecological sciences is limited by our least developed level of understanding. In most cases, this is the ecological information. As illustrated by several chapters in this book, this ecological understanding is now reaching the point at which we can start to incorporate finer-scale understandings of the social and political systems, and move towards a more sophisticated understanding of the ecology 'of' cities. However, studies of ecology 'in' cities will continue to play an important role in the short term, as we attempt to bring our ecological understanding up to a level that matches our understanding of social and physical patterns and processes within cities and towns.

Today, interest in the ecology of cities and towns around the world is growing in leaps and bounds. Not surprisingly, concurrent with this recent interest there has been a significant growth in the number of new academic and government programmes, and in research dollars spent on studying the ecology of human settlements. The resulting increase in published research certainly assists in filling the ecological information gaps mentioned earlier (Theobald, 2004). Cities vary enormously in their human population, history of development, cultural make-up, spatial extent and physical location, but there is still a remarkable similarity throughout the world in both their structure and dynamics. Ecological studies of urban and suburban ecosystems are loosely based on existing principles from such fields as geography and landscape ecology. Many of these studies already use a comparative approach (McDonnell and Hahs, Chapter 5), although the comparative aspect is not explicitly acknowledged and the studies involve primarily local or regional comparisons (e.g. urban–rural gradients). At present there has been little attempt to compare the ecology of different cities and towns at continental and global scales in order to construct a more comprehensive conceptual framework for creating comparable methodologies and general principles (i.e. confirmed generalisations).

The purpose of this book is (1) to evaluate the current state of understanding of the ecology of cities and towns around the world, and the methodologies used

to obtain this information; (2) to provide examples of how ecological information has been effectively integrated into urban management and planning schemes; and (3) to explore the opportunities and challenges of developing a comparative approach to the ecological study of cities and towns.

The book is separated into four sections, each of which contains contributions from leading scientists, landscape architects and planners in the field. Part I provides a foundation for evaluating the merits of challenges of conducting comparative studies of cities and towns. Several chapters also explore the theoretical underpinning of the science and provide examples of conceptual frameworks for conducting the research. Most of the chapters provide an assessment of the current urban ecology literature, but this collection of reviews is unique in that it includes research conducted not only on terrestrial habitats but also freshwater, estuarine and marine environments. Chapter 5 explicitly investigates the past, present and future uses of comparative ecology, and presents some suggestions about how to expand the scope of comparative studies of cities and towns to continental and global scales. Historically, the study of urban and suburban environments has been conducted in developed countries; Chapter 6 explores the application of the existing urban ecology conceptual frameworks to the study of urban environments in South Africa. The final chapter in this section explores the use of models as tools for conducting comparative studies of cities and towns.

Part II provides an up-to-date assessment of the research questions, hypotheses, methodologies and statistical analyses currently used by leading urban ecologists to understand the ecology of animals, insects, plants and ecosystem dynamics of cities and towns located in both the Northern and Southern Hemispheres. The chapters in this section broaden the current level of understanding of the ecology of urban environments by investigating not only the typical urban and suburban terrestrial environments, but also marine habitats, roadsides and front yards. It is impossible in a book of this size to cover every current research topic, but our goal is to highlight some of the seminal studies that are currently being conducted in the hope of stimulating new research on cities and towns.

Part III includes a collection of chapters by ecologists, landscape architects and planners that provide concrete examples of how the integration of ecological understanding and design principles can be used to create more sustainable cities and towns. They describe techniques for analysing the structure of urban and suburban landscapes and methods of conducting ecological assessments. Chapter 23 explores the similarity of garden and park forms around the world and suggests how new designs and plantings can help maintain biodiversity and ecological processes in human settlements. There are several chapters

that provide unique insights into preserving biodiversity in cities and towns as well as preserving and managing specific habitats such as remnant patches of vegetation, parkland, streams and wetlands. One of the major impacts of cities and towns is the creation of new developments. Chapter 27 explores how the integration of research from several fields into design and building practices can assist in preserving biodiversity and improving the quality of life for city dwellers.

There are five chapters in Part IV which include three different types of commentaries. Chapters 30 to 32 provide specific opinions on topics related to the ecological study of cities and towns, and the integration of scientific information into urban and landscape planning. Chapters 33 and 34 are summaries of the proceedings of the original Melbourne workshop. They provide some insights into the flavour of the meeting and an indication of future opportunities in the field, especially those related to conducting comparative studies. Finally, Chapter 35 provides an overall synthesis of the themes that have arisen from the book and also outlines some directions for future opportunities for research and integration of scientific understanding into landscape and urban design.

Most chapters were originally presented as papers at the two meetings. However, a few additional chapters have been included to provide greater coverage of the current scope of knowledge related to the ecology of cities and towns. During the original meetings and in the preparation of this book, all the participants/contributors were challenged to think more broadly about the state of our knowledge and identify the gaps as well as the effectiveness of our current methodologies and tools. They were also asked to consider ways to improve the integration of ecological, physical and socio-economic data into our studies in order to achieve better conservation and design outcomes. Finally, we encouraged them to assess whether there are general principles about the components of the systems they study and their interactions, and the opportunities that exist to conduct further comparative studies. These general themes are woven throughout the book and will be evident to the reader by the number of cross chapter references. We hope that this volume will provide a useful collection of conceptual frameworks, research results, methodologies, designs and outcomes which will stimulate new integrated research in the field and assist in developing general principles for creating sustainable cities and towns in the future.

Part I OPPORTUNITIES AND CHALLENGES OF CONDUCTING COMPARATIVE STUDIES

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Comparative urban ecology: challenges and possibilities

JARI NIEMELÄ, D. JOHAN KOTZE AND VESA YLI-PELKONEN

Introduction

Our research has been inspired by the views of Dennis and Ruggiero (1996) who emphasised that even simple inventories, if done with quality and consistency and repeated over large geographical areas, can provide valuable understanding about ecology and the impacts of humans across the world. Approximately 75% of the human population in industrialised countries lived in cities in 2003 and it is projected that half of the world's population will be urban by 2007 (United Nations, 2004). In order to ensure that urban areas are planned for the well-being of both city dwellers and urban biodiversity, knowledge of the responses of the urban ecosystem – including ecological and human components – to the influence of urbanisation is pivotal (McDonnell and Pickett, 1990; Niemelä, 1999a).

Urbanisation creates patchworks of modified land types that exhibit similar patterns throughout the world. Nonetheless, little is known about whether these changes affect biodiversity in similar ways across the globe, or depend more on local conditions (Samways, 1992). Thus, there is a need for comparative, international research to assess the effects of these activities on native biodiversity, and, where possible, to minimise adverse effects (Dennis and Ruggiero, 1996; Andersen, 1999). Such research could potentially distinguish globally recurring patterns and convergence from more local phenomena. The new knowledge could enhance the development of urban ecology as a scientific discipline and

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foster international collaboration among researchers and managers in finding ways to mitigate the adverse effects of human-caused landscape change.

A useful framework in which to investigate the biotic and abiotic effects of urbanisation is the urban–rural gradient approach (McDonnell and Pickett, 1990; Blair and Launer, 1997; McDonnell *et al.*, 1997; Niemelä, 1999a; Niemelä *et al.*, 2002; Pickett *et al.*, Chapter 3). Such gradients, from densely built city cores to increasingly rural surroundings, reflect diminishing intensities of human intervention on originally similar land bases. Although types of ecosystems and human impacts differ across the world, making global comparisons difficult, urban landscapes are relatively comparable around the world and provide a useful framework for comparative work on a global scale (Niemelä, 1999b).

This kind of research on ecology in cities forms the necessary basis for ecology of cities, which integrates ecological and human systems in the urban setting. However, we still lack a firm understanding of ecology in cities, partly because ecologists have been reluctant to pay attention to urban areas and partly because of a lack of a theoretical framework within which to conduct such research. This is particularly true for marine and coastal habitats (as discussed by Chapman and Underwood, Chapter 4; Chapman *et al.*, Chapter 9). It appears that theories developed in and for other environments do not always do justice to the special features of urban ecological systems (Niemelä, 1999a).

The aim of this chapter is, first, to discuss the theoretical and conceptual basis of urban ecology. In particular, we examine whether theories developed for other environments are useful in studying ecological questions in cities. Second, we use examples from across the world in a comparative manner to highlight the special features of urban ecological systems and to show how such studies can contribute to the development of theory in urban ecology. To deepen the comparative aspect, we discuss two different cases of comparative work: one dealing with a conceptual framework of urban ecosystems developed in the United States and applied in Finland, another based on a common methodology for examining biotic responses to urbanisation in visually similar urban land-mosaics in different parts of the world.

What is urban ecology?

In order to define the concept ‘urban ecology’, the constituent words ‘urban’ and ‘ecology’ need to be discussed. ‘Urban’ refers to a human community with a high density of people, their dwellings and other constructions. Numerical definitions of urban do exist (based, for example, on population density), but a general definition is more practical for research purposes. A useful way to

define 'urban' is to consider gradients of land use. According to Forman and Godron (1986), the intensity of human influence divides landscapes into five broad types spanning the continuum from pristine natural environments to urban centres highly modified by people. At the pristine end of the gradient, natural landscapes support mostly unmanaged native biota, while the managed landscape consists of planted and/or managed native or non-native species. In the middle of the gradient, cultivated landscapes consist of a matrix of agricultural lands that can be either crops or grazing land. The suburban landscapes include low- to moderate-density housing, yards and roads. The urban end of the gradient represents landscapes of the most intense human influence dominated by high-density residential and commercial buildings, roads and other paved surfaces. Despite obvious differences, all these land-use types may include patches of other types (Forman and Godron, 1986). This urban-to-rural gradient forms a fruitful concept for examining ecological effects of the intensity of human influence on the biota (McDonnell *et al.*, 1997). Although this approach has been shown to be successful in terrestrial habitats, the usefulness of the urban–rural gradient (or its equivalent) has not been extensively explored for identifying human impacts on coastal habitats extending out from centres of the human population.

The meaning of the word 'ecology' has expanded during recent decades (Egerton, 1993). More specifically, Haila and Levins (1992) recognise four different meanings of the term. Ecology the science investigates nature's 'economy' (flows of matter and energy or the distribution and abundance of organisms), while ecology as nature is seen as the resource base for humans. Ecology the idea is a concept that views human existence in relation to ecology the science ('human ecology') and ecology the movement refers to political activities related to ecological and environmental issues (the 'green' movement).

As a consequence, 'urban ecology' is a complex concept with different dimensions. However, here we define 'ecology' as natural science but keep in mind its other definitions. The different approaches to urban ecological research indicate that urban ecology is a broad discipline which can be defined as ecological research in the urban setting (Rebele, 1994). In addition to the scientific component, urban ecological studies usually aim at applications of research in the planning and management of urban green areas (Wittig and Sukopp, 1993). Thus, urban ecology is by nature an applied science.

It is useful to distinguish between two complementary approaches to the study of urban ecology. Research into ecology *in* cities refers to studies on the physical environment, soils, fauna and flora, and differences between urban and other environments (Grimm *et al.*, 2000; Pickett *et al.*, Chapter 3). This kind of research forms the necessary foundation for understanding

ecological processes and patterns in urban ecosystems. Research into the ecology *of* cities builds on the foundation formed by research into ecology in cities and may use partly similar methods. The ecology of cities approach, however, uses the ecosystem framework and studies the urban area as an interactive system including both human and ecological components. Clearly, a framework for studies in ecology of cities should include both ecological and human systems.

Thus, it is evident that as well as being of applied nature, urban ecology is multidisciplinary. Both urban research and its applications would gain from increased collaboration between ecologists, sociologists and urban planners (see Blood, 1994). Ecological research and its applications would benefit from the input of knowledge of human actions in urban areas, while the development of residential areas that maintain and improve the quality of life, the health and the well-being of urban residents would benefit from a better ecological understanding.

Urban ecology: a neglected field of ecological studies?

Traditionally, mainstream ecological research has neglected urban areas. Ecologists have focused on pristine or rural nature, and have considered urban nature as less 'worthy', owing to strong human influences in cities (Gilbert, 1989; McDonnell and Pickett, 1993a; McDonnell, 1997). For example, although 80% of the Finnish population is urban (and increasing), urban studies have not been appreciated by ecologists in the country. As a consequence, urban ecological research is not well developed in Finland, biodiversity of urban habitats is poorly documented in many cities, and thus baseline information about urban ecology is scarce. As a result, the possibilities of applying ecological knowledge in urban planning are limited. This unsatisfactory situation has been recognised by planners, managers and concerned citizens, many of whom regard the use of scientifically gathered ecological information an integral tool in urban planning (Haila, 1995; Yli-Pelkonen and Niemelä, 2005).

Luckily, this state of affairs appears to be changing for several reasons. First, profound changes in ecological understanding are taking place (Pickett *et al.*, 1992; McDonnell, 1997; Pickett *et al.*, 1997c). The traditional view of ecology has been that of a balanced nature (see Pimm, 1991), i.e. that ecological systems are in equilibrium. Disturbed systems are in disequilibrium, and, therefore, not 'good' nature according to the equilibrial view. This view of ecological systems is giving way to dynamism and the recognition that systems are often not in equilibrium.