CHAPTER ONE

Urban ecology

KEVIN J. GASTON

What is urban ecology?

Real ecologists study wild and natural places. At least, that has been the view which has dominated the field of ecology for much of its existence. Some lone voices argued that this was a narrow, unrealistic and unhelpful perspective, but their arguments were easily ignored by the majority as they focused on their supposedly pristine field sites. This was always something of an irony, as surely there was never any real doubt that less wild and natural areas equally functioned as ecosystems, containing the same essential components (e.g. water, soil, microorganisms, plants, animals), and being subject to much the same processes (e.g. carbon, nutrient and water cycles). Thus, towards the close of the twentieth century and the dawning of the twenty-first, this viewpoint changed radically. Growing numbers of studies focused on the patterns and processes structuring systems that had been heavily modified, or were essentially created, by human activities. This change was particularly evident with respect to the ecology of urban areas, with numerous research studies, commentaries and reviews being published (e.g. Gilbert 1989; McDonnell & Pickett 1993; Grimm *et al*. 2000, 2008a, 2008b; Marzluff *et al*. 2001, 2008; Pickett *et al*. 2001; Kelcey & Rheinwald 2005; Forman 2008). Indeed, not only did ecologists begin to study urban systems in earnest, but urban ecology also began to influence the study of ecology more widely. In short, urban ecology came of age.

The rise of urban ecology

Ecology has variously been described as the scientific study of the processes determining the abundance and distribution of organisms, of the interactions between organisms, of the interactions between organisms and the environment, and of the flows of energy and materials through ecosystems. Urban ecology is quite simply therefore the study of these issues within urban systems.

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The rise of urban ecology has arguably been fuelled by seven things. First, there has been mounting recognition that much of the world is now covered by human-dominated ecosystems, and that humans are integral to any general models and understanding of ecosystems. Urban systems are simply at one extreme of the spectrum from areas which are entirely uninfluenced by human activities (now very scarce, if existing at all) through to those which are predominantly shaped by interactions with people.

Second, a growing proportion of the Earth and its human population has become urbanised, and in more and more regions almost everybody has come to live in towns and cities. Thus, an understanding of the ecology of urban systems has become much more obviously relevant to people's lives and to solving the environmental problems that they face. This has resulted in particular in attention being given to the ecosystem services (the benefits humans obtain from ecosystems) associated with urban areas, the influence of different forms of urban development and management on them, and how these services can best be maintained and improved (e.g. Bolund & Hunhammar 1999; Alberti 2005).

Third, urban areas have been studied more closely in order to elucidate the connections between urban and rural landscapes. Indeed, urban areas are disproportionately responsible for many of the pressures that more natural ecosystems elsewhere experience. In large part as a consequence of the high proportion of the human population that they account for, urban systems make major local, regional and global demands for resources and for waste assimilation (e.g. Rees 1992; Folke *et al*. 1997; Millennium Ecosystem Assessment 2005; Bagliani *et al*. 2008). They are thus the primary drivers of habitat loss and fragmentation (particularly through demands for food and timber) and the multitude of consequences that follow, are the principal source of greenhouse gas emissions (and hence have significant implications for climate change) and many other atmospheric and aquatic pollutants, and are major sources for biological invasions (Grimm *et al*. 2008a; Trusilova & Churkina 2008).

Fourth, the potential significance for people's health and wellbeing of their having direct interactions with the natural world has become progressively apparent (e.g. Ulrich *et al*. 1991; Kaplan 1995; Health Council of the Netherlands 2004; Maas *et al*. 2006; Fuller *et al*. 2007). Because such interactions are often at their most sparse and least frequent in urban ecosystems, these areas have also become the places in which this significance is most easily demonstrated, in which observational studies and experiments can most readily be conducted, in which a need to understand how these can be improved becomes most apparent, and in which actions to do so are most pressing.

Fifth, the ecology of urban areas is rather different from that of other systems, owing to the pervasive influence that human activities have on

ecosystem structure and function. This makes them particularly interesting subjects of ecological study because it means on the one hand that models cannot necessarily simply be borrowed from more traditional ecology and applied successfully to urban systems, and on the other hand that the development of models appropriate for urban ecology may enrich ecological research at large, especially as the human influence on ecological systems rises more generally.

Sixth, and more methodologically, urban ecology has been fuelled by the recognition that an understanding of urban ecosystems requires an approach that draws on multiple disciplines, and by a generally more positive and constructive attitude to interdisciplinary research than has typified much of the recent history of academic discourse. Studies of urban ecosystems require inputs from social, behavioural and economic sciences, as they are profoundly shaped by human activities, attitudes and choices (McIntyre *et al*. 2000; Alberti *et al*. 2003; Hope *et al*. 2003; Kinzig *et al*. 2005; Grove *et al*. 2006).

One final stimulus to the study of urban ecology has been provided by the discovery, which at the time was surprising, that in many regions of the world areas that have experienced urban development often coincide with those that support high native species richness and endemism (Kerr & Currie 1995; Balmford *et al*. 2001; Chown *et al*. 2003; Gaston & Evans 2004; Gaston 2005). Conservation biology has thus had to engage not simply with generic issues of human population growth, but more particularly with understanding just where that growth is taking place, what its consequences are, and how to maintain habitats and species of conservation concern in areas with high human densities.

Ecology in and of urban areas

Urban ecology can be viewed from two, closely related, perspectives (Grimm *et al*. 2000; Pickett *et al*. 2001). The first addresses ecology *in* urban areas. It is closely allied to traditional ecology, in that it typically investigates ecological patterns and processes in urban areas in much the same way as they might be examined in any other environment. That said, increasingly there is a much greater socioeconomic component, acknowledging the dominance of human activities in shaping urban ecosystems.

Studies in urban areas tend to be of four broad types: (i) comparison of different land-use types within an urban setting; (ii) comparison of an urban area with a nearby 'natural' area; (iii) monitoring of an urban area through time; and (iv) gradient analysis (McIntyre *et al*. 2000). A particularly dominant theme has been the study of rural–urban gradients, in which typically the ecological characteristics of sites are compared along a, usually spatial, transect of increasing urbanisation (e.g. McDonnell & Pickett 1990; Blair 1996;

Guntenspergen & Levenson 1997; McDonnell *et al*. 1997; Pouyat *et al*. 1997; Carreiro *et al*. 1999; Niemelä *et al*. 2002). However, having resulted in many valuable insights, this dominance is fading with a greater diversification of approaches. Indeed, even studies treading this same route now seem to be considering multi-dimensional environmental gradients more frequently. Temporal patterns have received far less attention in urban environments than have spatial patterns, largely because of a lack of appropriate data, although this is also beginning to change (e.g. Zapparoli 1997; Morneau *et al*. 1999; Chocholoušková & Pyšek 2003; Puth & Burns 2009).

The second perspective on urban ecology is a more system-oriented approach, the ecology *of* urban areas. The distinction from ecology *in* urban areas is not so much one of methodology per se, but rather something of a conceptual shift. The ecology of urban areas concerns how those areas function as aggregated wholes. There has thus been a growing number of studies particularly of aspects of the ecology of entire cities (e.g. Hadidian *et al*. 1997; Kent *et al*. 1999; Grimm *et al*. 2000; Turner 2003; Pickett & Cadenasso 2006; Davies *et al*. 2008; Walton 2008). A logical extension of such work is then the comparison of the ecologies of different cities, and this is indeed developing rapidly, predominantly in relation to patterns of land cover and assemblage composition (e.g. Pyšek 1998; Turner *et al*. 2004; La Sorte *et al*. 2007).

Neither the ecology *in* urban areas nor the ecology *of* urban areas perspective has particular precedence, and knowledge will advance most swiftly when both are employed. An analogy might perhaps usefully be drawn between local ecology and macroecology (Gaston & Blackburn 2000). Local studies have dominated ecology for much of its existence and have contributed much to understanding of the dynamics of populations, communities and ecosystems. However, a great deal remains unexplained without also taking a much broader view, and placing local study sites in the context of landscapes and the processes that shape the spatial flows of individuals and materials. It is when the two views are combined that the greatest insights and predictive power can be achieved. Likewise, the combination of studies of ecology *in* and ecology *of* urban areas is likely to bring about the most rapid advances in understanding, particularly because of the inherent complexity of urban systems.

To date, urban ecology has predominantly been an observational science, given the practical constraints on conducting field experiments posed by issues of land ownership and access, security from interference and the spatial variation of urban landscapes. However, some small-scale experiments have been conducted (e.g. Denys & Schmidt 1998; Gaston *et al*. 2005), and there may be considerable potential to do so at much larger scales through collaboration with urban designers (Felson & Pickett 2005).

'Wicked' problems

More so than in research into many other ecosystems, studies in urban ecology are almost invariably conducted against the background of a concern to understand the consequences of particular human-wrought changes to the environment. Whether the focus be a particular species, habitat or ecosystem process, and whatever motivation drove the original investigator, such studies are apt to be interpreted in terms of the successes or failures of past urban planning, how the structures that resulted can best be exploited or modified, and how future planning should be conducted. A measure of the maturity of the field of urban ecology will be the extent to which these considerations are realistic, not only about the complexity of urban ecosystems, but also about the formidable array of pressures, constraints and compromises, and the interactions thereof, that shape the planning process and contribute to (without being able entirely to dictate) the resultant emergent urban systems. As the Royal Commission on Environmental Pollution (2007, p. 5) states, urban systems 'have evolved in particular ways as agglomerations of people; accretions of buildings and roads; infrastructures for water and energy supply and the removal of sewage and waste; public and private spaces; places of business and residence; locations for the production and consumption of goods and services; facilities for entertainment, education and health; and so forth'.

It has been argued that urban environmental management presents a classic case of a 'wicked problem' (Royal Commission on Environmental Pollution 2007); 'wicked' in the sense of nasty or vicious, rather than passing any ethical judgement. Rittel and Webber (1973) observed that the kinds of societal problems that planners deal with are intrinsically different from archetypal problems in science in that they are ill-defined and cannot be definitively solved. Their characterisation of the wickedness of planning problems provides valuable context for studies in urban ecology, but arguably also extends to some of the issues which those studies themselves set out to address: (i) there is no definitive formulation of a wicked problem – the process of formulating the problem and of conceiving the solution are essentially the same; (ii) wicked problems have no stopping rule – because there is no definitive formulation of the problem there is no point at which *the* solution has been found; (iii) solutions to wicked problems are not true-or-false, but good-or-bad – the particular solutions are likely to depend on who provides them; (iv) there is no immediate and no ultimate test of a solution to a wicked problem – any solution is likely to have many consequences, some of which will be unintended and unexpected, which play out over potentially long periods of time; (v) every solution to a wicked problem is a 'one-shot operation'; because there is no opportunity to learn by trial and error, every attempt counts significantly – this is because planning actions are seldom reversible but have so many consequences; (vi) wicked problems do not have an enumerable (or an exhaustively

describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan – the set of potential solutions and the extent to which they are permissible will depend on who provides them; (vii) every wicked problem is essentially unique – there are always particularities to a problem which may override the commonalities with other problems; (viii) each wicked problem can be considered a symptom of another problem; (ix) the existence of a discrepancy representing a wicked problem can be explained in numerous ways – the choice of explanation determines the nature of the problem's resolution; and (x) the planner has no right to be wrong – the objective is to improve a situation.

Prospects

Despite its relatively late emergence as an important component of the ecological research agenda, understanding of urban ecology has developed rapidly. The numbers of papers, books, symposia and conferences dedicated to the topic continue on steeply rising trajectories. Contributions appear increasingly frequently in high-profile general science journals as well as more subject-specific ones and, perhaps more tellingly, key findings are more regularly being cross-referenced in other fields of ecological and environmental science. All of this reflects a vibrant and fast moving research agenda.

Of course, much work remains to be done in urban ecology. Almost all of the subsequent, more detailed, chapters in this volume highlight questions for which answers are urgently required, and important topics that have remained poorly explored or are as yet unexplored. More generically, obvious issues for future work include (i) the ecology of towns and cities in developing countries; (ii) the relationship between the ecology of towns and cities and how urban areas grow; (iii) improved understanding of the role of history and culture in shaping the ecology of different urban areas; (iv) how the ecology of urban areas will alter as a consequence of climate change and other global change pressures; (v) more comparative work between different towns and cities; and (vi) more experimental studies.

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CHAPTER TWO

Urbanisation

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Unsurprisingly, knowledge of the pattern and process of urbanisation is key background to an understanding of urban ecology. However, of course, the necessary material lies largely in other fields of study. Moreover, it is widely scattered and rather poorly synthesised. This chapter therefore provides a broad but selective overview of some of the most important issues of especial relevance to urban ecology. In particular, it addresses what constitutes an urban area, how urbanisation occurs, the history of urbanisation, the scale of urbanisation (in terms of population and household numbers, land cover and ecological footprints), the structure of urban areas (in terms of location, size, form and composition) and, finally, the sustainability of cities. Whilst an attempt has been made to draw on an extensive range of examples, there is an inevitable and unfortunate bias towards the developed regions on which the vast majority of research, and the associated literature, has been focused.

What is urban?

Urbanisation is the process by which a rural area becomes an urban one, or the degree to which an area is urbanised (although some differentiate the former process as urbanisation and the latter as urbanicity). But what is an urban area? There is no simple answer to this question, although most of us would have an intuitive sense of what constitutes such an area and what does not, probably based on the numbers of people and the level of cover by buildings, transport networks and other such infrastructure. More formally, urban areas have, in practice, been distinguished in a wide variety of ways. These include using administrative or geopolitical boundaries (e.g. towns, cities, metropolitan districts), functional boundaries (based on flows of people or resources), human population size or density (of varying accuracy, depending on census techniques), housing numbers or density, land cover (commonly derived from satellite imagery) and/or other indicators of human activity (e.g. artificial

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