

INVASION ECOLOGY GOES TO TOWN: FROM DISDAIN TO SYMPATHY

Joëlle SALOMON CAVIN¹
Christian A. KULL^{1,2}

¹Institute of Geography and Sustainability
University of Lausanne, 1015 Lausanne, Switzerland

²Centre for Geography and Environmental Science
Monash University, Melbourne VIC 3800 Australia

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Abstract: How can one understand the increasing interest in “urban invasions”, or biological invasions in urban environments? We argue that interest in urban invasions echoes a broader evolution in how ecologists view “the city” in relation to “the natural”. Previously stark categorical distinctions between urban and natural, human and wild, city and ecology have foundered. Drawing on conceptual material and an analysis of key texts, we first show how the ecological sciences in general – and then invasion science in particular – previously had a blind spot for cities, despite a number of important historical and continental European exceptions. Then, we document the advent of an urban turn in ecology and, more recently, in invasion ecology, and how this has challenged fundamental concepts about “nativity”, “naturalness”, and human agency in nature. The urban turn necessitates more explicit and direct attention to human roles and judgements. Ecology has moved from contempt (or indifference) for cities, towards interest or even sympathy.

Keywords: Biological invasions, Historical perspective, Invasion science, Paradigm shift, Urban ecology

1. INTRODUCTION

Invasion ecology is going to town. That is, the study of biological invasions has started to pay attention to cities. The Stellenbosch workshop (for which this paper was prepared) marks a belated interest of invasion science in urban matters. It is a topic that is still only rarely and recently addressed head-on (e.g. Pyšek et al. 2011; van Ham et al. 2013; Francis and Chadwick 2015; Gaertner et al. 2015). The workshop also demonstrated the other sense of “going to town”: an eagerness to perform this new task as well as possible.

This interest in urban invasions parallels a global surge in attention to cities. In 2008 according to UN estimates, the world passed the threshold of fifty per cent of people living in urban settlements. Our hypothesis is that the recent growth in interest in urban invasions is not directly related to this surge in attention, but instead is more illustrative of a more general evolution in visions, ideas, and representations of “the city” held by society at large. In particular, among ecological scientists there has been an erosion of some of the key dualisms previously central to ecological thinking, such as cities vs. nature, anthropogenic vs. wild, or society vs. environment. Within ecology, there has been a move from disdain for – or ambivalence towards – the city, towards an engagement with, and even indulgence for, urban matters.

Our objective is three-fold. **First**, we seek to establish the historical urban blinders of ecology (in general) and invasion science (in particular). **Second**, we seek to investigate the intrusion of urban matters into ecology and invasion science. In each case, we seek to interrogate the underlying conceptual and practical reasons, and we also seek to highlight several exceptions, particularly in the historical and central European origins of urban ecology. **Finally**, we aim to identify conceptual openings made possible by the blurring of categories necessitated by invasion ecology “going to town”.

In terms of methodology, we investigate ecology, urban ecology, and urban invasions from a perspective attuned to concepts and categories in historical and comparative perspective. In particular, we focus on what have been called discourses, imaginaries, or social representations, referring to the kinds of widely-circulating ideas, communicated in text but also in diverse media, that can become institutionalized and have on-the-ground consequences. In the jargon of the social sciences, discourses are *performative* (in that they are not just manifestations of identities and imaginaries, but also contribute to constructing them) and they have *agency* (the capacity to have effects). As shown in studies dealing with conservation biology and ecosystem services (Salomon Cavin 2013; Kull et al. 2015), social representations influence research and practice despite often being implicit. Following a humanities style of structure and argumentation, we build our case on analyses of key texts in ecology and invasion science, on the discussion and critical evaluation of concepts and arguments in the published literature, and on previous studies in the philosophy, sociology, and history of science.

To set the scene, in **Section 2** we begin with the general tendency in ecology to prioritize the study of non-urban environments, which requires us to investigate the values and representations linked to ideas of “urban nature” and its antonyms like wild nature, pristine nature, countryside, and so on. We do this because the field of ecology is a crucial predecessor to invasion science. Then in **Section 3**, we take a more specific look at invasion science, evaluating and relativising the general absence of or ambivalence towards “the urban” in this specific research field over time. Next, in **Section 4**, we switch our focus to an alternative predecessor of invasion science: urban ecology, which of necessity incorporated different ideas about “the urban”. The specific recent turn towards urban invasions is justified in **Section 5**, which highlights four discourses behind this interest.

Finally, in the discussion, **Section 6**, we reflect on the conceptual implications of the urban turn.

2. URBAN BLIND SPOT IN ECOLOGY

Traditionally – aside from some important exceptions that we will discuss later – ecologists were reluctant to study urban nature. As noted by Marzluff et al. (2008), “despite the clear need for the focus of ecological research to be turned towards human dominated systems and particularly urban ecosystems, there is relatively little research activity in this area” p. 60 (see also McDonnell and Pickett 1990). Urban ecology was hardly visible in the mainstream journals of ecological and conservation science before the late 1980s and early 1990s (Wu 2014). The editorial introduction to the first issue of the then new journal *Urban Ecosystems* stressed the difficulties faced by scientists studying urban environments in publishing their research (Walbridge 1996). This blind spot persists: a recent analysis of more than 8,000 ecological studies found that only 4% assessed densely populated areas, the dominant focus being on relatively intact habitats (Martin et al. 2012). It is worth noticing that the urban blind spot is also noticeable in certain other branches of the environmental sciences, including the fields of environmental ethics and environmental philosophy (Gunn 1998; Light 2001; De-Shalit 2003), biogeography (Head and Muir 2006), and environmental history (Cronon 1992; Melosi 1993).

Why have ecologists and other environmental scientists often been reluctant to work on areas dominated by humans, particularly cities (McDonnell 1997: 85)? We highlight four principle reasons. **First** is that, for many scientists, cities are the antithesis of nature. Ecologist and others long preferred to study relatively intact ecosystems presumed to be closer to “real nature”, with cities being regarded as “anti-life” (Sukopp 1998) or “unnatural” (Gilbert 1989; McDonnell and Pickett 1993; McDonnell 1997; Francis et al. 2013; Wu 2014; Marris 2011). This distinction persisted despite inherent challenges in delimiting the frontiers between cities and nature, wild and anthropic, natural and not (Marris 2011). Invasive species no doubt contribute at times to perceptions of urban nature as “trash” ecosystems not worthy of study (Marris et al. 2013; Nagy and Johnson 2013).¹

The **second** reason is the perception that cities destroy nature (Kowarik 2013). Cities are agents of destruction, replacing habitat with concrete (Pyšek et al. 2011) and making resource demands and pollution impacts on the surrounding countryside. From an ecosystemic or metabolic point of view, cities have long been regarded as parasitic (Odum 1959; Broto et al. 2012) because rather than producing their own food, they encroach on the wider region, polluting water, air, and other resources. From an invasion point of view, cities can be perceived as dangerous as they are often points-of-entry for invaders, whether from ports or gardens, as we detail in section 5.

¹ There are parallels to views expressed at some historical moments in certain societies about the cultural purity or wholesomeness of the countryside and rural folk and the corresponding denigration of the urban as corrupted, decadent, traitors to the homeland (Salomon Cavin and Marchand 2010)

A **third** explanation for the disdain for urban ecosystems are their complexity, particularly due to the addition of societal drivers not included in the traditional frame of ecological theory. Indeed, avoiding direct human impacts was a common strategy in ecological studies because it helped make complex systems more analytically tractable (Corbyn 2010). More broadly, ecologists have primarily sought to understand their subjects of study in the absence of humans and have usually considered humans chiefly as agents of disturbance and not as integral functional components of ecosystems (Gilbert 1989; McDonnell and Pickett 1993; Clergeau 2010). As Sukopp (2002) pointed out, invasive species are key element of this urban biological complexity: “A major reason for the (relative) unpredictable nature of succession in urban ecosystems is the high frequency with which they are invaded by aliens species; the biogeographical spectrum of species in cities is very different from that of the surrounding countryside” (p. 381). With their high proportion of exotics and mixture of planted and spontaneous vegetation, cities are “bewildering” for ecologists (Gilbert 1989).

Finally, a **fourth** possible reason is pragmatic. There are logistical problems incurred from working in urban settings, such as difficulty in obtaining permission to conduct large-scale experiments or field observations on private property (Lachmund 2012) as well as vandalism to field equipment (Mcintyre et al. 2000).

3. URBAN IRRELEVANCE IN INVASION BIOLOGY ?

If mainstream ecological research was characterized by an urban bias, what about the research on biological invasions? What importance has the urban question carried in the modern field of invasion biology? What place was given by seminal, field-defining researchers to the urban milieu? Our hypothesis is that despite a number of oft-forgotten urban deep roots, until recently the “urban” has largely been irrelevant to mainstream invasion biology.

In order to investigate this hypothesis, we combine a historical contextualization of the field of invasion biology with analysis of a number of representative texts. The history of invasion science has previously been discussed elsewhere (e.g. (Chew 2006; Kueffer and Hadorn 2008; Richardson and Pyšek 2008; Davis 2009; Chew and Hamilton 2011; Hobbs and Richardson 2011)). What we do here is highlight the social and historical context of the field that made it prone to being interested (or not) in urban issues, or prone to certain depictions of “the urban”. We illustrate with examples from key publications. **Figure 1** illustrates the main flow of ideas that we develop in this section: the emergence of important fields at different historical moments, and their attention to particular types of environments on an urban-rural-wild spectrum reflecting degrees of anthropization.

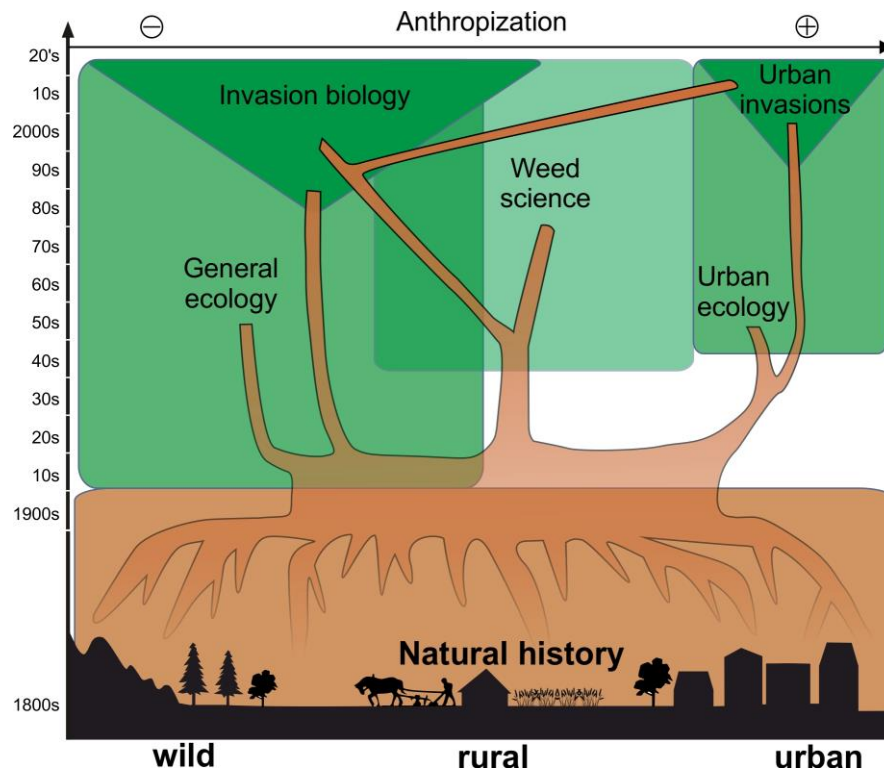


Figure 1: The historical roots of urban invasion studies across the rural-rural-wild spectrum. Source: authors. Artwork: Lionel Cavin.

Deep historical precursors of urban invasion research: natural history.

First, we turn our attention to the 18th century research tradition best characterised as ‘natural history’ and which lies behind much modern ecology (Chew 2011)(see **Figure 1**). In this tradition, the urban blind spot does not seem to have been so relevant, despite the attention focused on the wilderness adventures of the likes of von Humboldt or Darwin. Unlike their 20th century ecological successors, most naturalists, both well-known and anonymous, were interested in – or constrained to – studying nature in their immediate surroundings before looking for pristine places. They focused on, for instance, the flora of gardens, parks, walls, and ruins within and near cities, and participated in local amateur societies like the London Natural History Society (Douglas 2017).

Interestingly, these investigations of nature in and near the city were often focused on species introduced directly or indirectly by people and on their effect on the evolution of native flora. Important examples include naturalists like the Swede Peter Kalm, the Dane Joakim Frederik Schouw, the Franco-German Adelberg von Chamisso, the Swiss Basil Caspari Bauhini, Alphonse de Candolle and Albert Thellung or the Finn Kaarlo Linkola. To illustrate with one of the above, Chamisso described the effects of the introduction of non-native species on urban flora over 200 years ago (see Sukopp 2002; Chew 2006, 2011; Kowarik and Pyšek 2012).

A second illustrative figure in the above list is botanist Albert Thellung, who operated in the early 20th century as the natural history tradition gave way to disciplines like ecology (Chew 2011; Kowarik and Pyšek 2012). Thellung

compiled alien floras for two urban areas and their surroundings: Montpellier (southern France) and Zurich (Switzerland), created classification schemes for types of introduced species, and highlighted the role of cities as entry points for non-native species, such as via the trade in wool. His work informed the Braun-Blanquet (1932) school of ecology, influential in the 1930s. Precursors such as Thellung are often poorly known in the field of invasion biology, which generally looks only as far back as Charles Elton's 1958 classic book (Chew 2006, 2011). This perhaps due to linguistic reasons (many of the above naturalists published in languages other than English), but perhaps also reflects the increasing focus of dominant strains of ecology on non-human environments (Kowarik and Pyšek 2012). However, as a 21st century focus on urban invasions takes form (this special issue), it is crucial to acknowledge that some of the early precursors of invasion science were already working on the city.

Postwar precedents

A simplistic narrative could see today's nascent focus on urban invasions as the natural expansion of an Eltonian invasion science born in a wildland-focused ecology towards an unoccupied niche, the city. Yet, as **Figure 1** emphasizes, two other post-war trunks can be seen as relevant to the story.

The first is agronomic research on weeds and pests, which shows that invasion science did not just come out of general ecology. Governments began establishing agricultural services for commercial crops in the late 1800s, and by the turn of the century agronomy had developed into a university discipline. Pioneers such as Wilfred Robbins and Alden Crafts at the University of California, Davis initiated a separate 'weed science', publishing the first edition of a field-defining textbook in 1942 defining weed types and control strategies. Weed science boomed with the development of chemical herbicides in the postwar period (Timmons 1970; Tilman et al. 2001; Zimdahl 2010; Kull and Rangan 2015). It goes without saying that a field focused on farming paid no special attention to cities, though early 20th Century public health officials did use weed science knowledge in their focus on problematic plants such as the allergy-producing ragweed (Mitman 2004).

Second, a biologically-oriented urban ecology emerged in the post-war period. Although the dominant Anglophone literature in urban ecology underscores an urban blind spot in ecology, it is worth noting that there were other traditions, notably in continental Europe, not subject to the blind spot (Wittig 1991; Pyšek 1995; Sukopp 2002). For many, the field of urban ecology as subfield of biological science was pioneered by what has now come to be called the Berlin school (Wu 2014).² Researchers from Berlin, surrounded by the Iron Curtain, were confined in their possibilities for fieldwork (Lachmund 2007). The recording of urban vegetation notably started in Berlin; in addition, Berlin's botanists paid attention to how nature re-conquered wartime ruins (Sukopp 2002), emphasizing nature's redemptive qualities in "dead cities" (Davis 2002). In 1973, Herbert Sukopp (Sukopp 1973) published an article in which he pleaded for the recognition of the metropolis as an object of ecological research. Despite the redoubtable

² We write "urban ecology as a subfield of biological science" to distinguish it from the well-known "Chicago school" of urban ecology, which is a sociological endeavor to explain cities as socio-economic systems using concepts borrowed from ecology.

development of urban ecology since then, categorized as either “ecology in the city” and “ecology of the city” (Grimm et al. 2000; Wu 2014), this subfield was until recently still relatively marginal within the biosciences.

The rapid ecological changes on bombed sites not only stimulated the first peak of activity in urban ecology. It was also a stimulus for interest on invasive species, because those derelict sites were perfect places for the study of introduced, invasive, and synanthropic plants and animals (Douglas 2017). Following on from the pioneering work of the Berlin school, a number of publications in urban ecology directly addressed urban plant invasions around the world. A notable example is Rapoport et al.’s (1983) study of the flora of Mexico City which was supported by the Man and the Biosphere Program. This study is largely dedicated to invasive species and their relation to colonization; it cites publications on urban invasions in different parts of the world like the US (Bornkamm 1975), Brasil (Müller 1970), Canada (Joyal 1970), Poland (Ćwikliński 1971; Faliński 1971), Germany (Sukopp 1980) or Australia (Bridgewater and Backshall 1979). It is clear that invasions were an important topic in 1970s urban ecology literature.

Establishing invasion ecology: absence of the urban

While interest in weeds and pests, as well as in alien flora and fauna, has a long history, invasion biology in its current form is a late 20th Century science. It arose largely out of the ecological sciences, which as we documented in section 2, often carried a bias towards natural areas (**Figure 1**).

The much-cited book *The Ecology of Invasions by Animals and Plants* by British ecologist Charles Elton (1958) is widely seen as marking the beginning of the systematic scientific study of biological invasions (Richardson and Pyšek 2008; Richardson 2011). Elton’s masterpiece tackles a diverse variety of topics under the theme of invasions, yet he only incidentally mentions words like “city” or “urban” or “town”. This sets a pattern for much future literature on invasions, where cities, settlements, and urban landscapes are not so much absent from texts, but just mentioned as places, or habitats, within which to describe and analyse particular cases of invasion.

There is a documented gap between Elton’s book and the later surge of interest in invasions, with few publications on invasions between the late 1950s and the 1970s (Lockwood 2007; Richardson and Pyšek 2008; Vas et al. 2017). One exception was the 1964 Asilomar conference and subsequent book *The genetics of colonizing species* (Baker and Stebbins 1965). Yet this book talked about colonizers, founding populations, introductions, migrations, and spread without using the Eltonian language of invasion (Davis 2009); it also ignored urban aspects.

The birth of the modern field of invasion biology dates back to the 1980s. Large international research consortia provided an important push. The ‘SCOPE 37’ research programme of the International Council of Scientific Unions launched in 1982 was a major catalyst for growth in this field (Simberloff 2013; Kull and Rangan 2015). It explicitly sought to build on pest and weed sciences in order to focus on the role of invasions in the balance, health and function of ecosystems, understood as “natural” or non-human (and certainly non-urban). The aim of SCOPE 37 was to “build on the considerable knowledge base available on invaders

of agricultural systems but that it should concentrate its efforts on natural systems where there had been considerably less attention” (Drake et al. 1989).

The landmark review published at the end of the SCOPE program (Drake et al. 1989) does not hold any trace of an ‘urban invasions’ focus. While the human role in shaping invasions is abundantly cited (species co-evolve with humans and then invade elsewhere; species transported by pathways of commerce; human disturbance of environments), there is no special place accorded to cities. The mention of cities is entirely incidental – the most compelling moment is in the chapter by James Brown on patterns of invasion, where he mentions suburban Miami habitats invaded by lizards as an example of habitats with a depauperate fauna “susceptible to invasion” (p. 96).

Institutionalisation of modern invasion biology: little urban interest

The field of invasion biology was institutionalized in the 1990s into science, policy, and programs (see Vas et al. 2017). Publications on invasions grew ten-fold in the mid-1990s; new specialized journals like *Biological Invasions* or *Diversity and Distributions* were founded under field-leading editors and SCOPE participants Daniel Simberloff and Dave Richardson; governments funded programs like the European Commission’s project to inventory invasive species (DAISIE, www.europe-aliens.org) or the Global Invasive Species Programme (GISP) and diverse national and international legislation.

The landmark ecological publications of this period continue the pattern of only incidental or contextual references to urban matters. Cronk and Fuller (1995)’s *Plant Invaders* does not mention any urban aspects, unsurprisingly given the subtitle *The Threat to Natural Ecosystems* which quite clearly reflects the dominant ecological framing of the “natural” as more interesting than its opposite, the “urban”. Williamson (1996) is the only single author overview of the field published in the 1990s; this text also does not engage with any urban issues. Likewise, Myers and Bazely (2003)’s *Ecology and Control of Introduced Plants* includes cities only incidentally as descriptors for types of habitats or places where invasive species are counted or introduced. At a more general level, the more policy-oriented, and anthropocentric *Millennium Ecosystem Assessment* includes many mentions of urban issues and processes, as well as many mentions of the challenges of biological invasions, but never both at the same time (MEA 2005).

The pattern holds even in the most recent 10-year period. Mark Davis’s ecological science textbook *Invasion Biology* (2009) does not shy away from using examples in urban environments, but focuses on processes of community ecology and affords no particular importance to urbanity and urban issues – it is just one habitat of interest among others. The contributions to Richardson’s *Fifty Years of Invasion Ecology: the Legacy of Charles Elton* (2011) do not single out the urban either, aside from some passing references.³ In the concluding chapter, which analyses 500 papers published on biological invasions in 2008, urban ecology is not identified as a topic of research. When Richard Hobbs (another alumnus of the

³ For instance, the ‘urban’ appears in the chapter by Blackburn on bird invasions (p. 168 ff.), where he notes that “Exotics species are frequently chosen to be commensal with humans and unsurprisingly, urban environments often favour exotic species ...”

SCOPE program) published his important edited volume on *Novel Ecosystems* (Hobbs et al. 2013), the contributors address both urban ecosystems and invasions, but without any overlap between the two concepts. Finally, this pattern of non-engagement is echoed in the recent text *Invasive Species*, part of Oxford University Press's "What everyone needs to know" series (Simberloff 2013). This is a magisterial yet accessible end-of-career overview textbook written by Daniel Simberloff, one of the most prominent invasion scientists. Again, all mentions of urban or city are inconsequential, not important to the discussions of science and policy at hand. The index lists dozens of obscure islands but not a single city.

The above review shows clearly that the 'urban question' was either *excluded* (i.e., defined to be outside of the scope of interest via a focus on the invasion of natural ecosystems), or *ecumenically included*, with the urban considered as one ecosystem among others – with certain characteristics but no special emphasis. The recent interest in urban invasions appears to intend to go a step further, to engage more deeply with the particularities of urban areas and the special questions they raise.

Human dimensions arrive: urban hints

In the 2000s, parts of invasion ecology took a greater interest in the so-called 'human dimension', and in turn, some social scientists began paying attention to biological invasions (Vas et al. 2017). In some of the resulting publications one can see the beginnings of a consideration of urbanity and urban processes as a particular realm of interest.

The first major work to deal with 'human dimensions' was *The Great Reshuffling*, edited by Jeffrey McNeely (2001). The keyword 'urban' appears some 30 times in the book. McNeely's introduction gives four reasons why invasive species are a human problem, including that invaders are more prevalent in habitats altered by humans, including crop fields, settlements, and roadways. He addresses the urban question head-on on page 9-10, where he writes

"Linked to the global marketplace, the world is becoming increasingly urban, with half the world's population living in cities at the turn of the century. Cities tend to be the focal points of the global economy and the entry points for many invasives. Many invasive species are most prolific in urban and urban-fringe environments where long histories of human disturbance have created abundant bare ground and many opportunities for invasion. Many urban dwellers seek ornamentals from a wide range of sources, and these may become invasive. For example, Berlin has 839 native species of plants and 593 aliens (Kowarik, 1990). Urbanization involves large and mobile populations that can easily escape the environmental penalties from mis-using resources. Further, they are seldom aware of the problems of invasive species because they have essentially lost their connections to the natural environment... [p10] Settlement patterns also involve transportation links, and the distribution of many invasives seems to follow transportation corridors. Thus human settlement patterns, too, are part of the invasive species issue."

These wide-ranging themes are supported by portions of the contributed chapters, though there is no single place aside from the above passage where an urban question is comprehensively addressed.

McNeely's book was followed in 2011 by an edited volume on *Invasive and Introduced Plants and Animals: Human Perceptions, Attitudes, and Management* that, while global in scope, gives extra place to case studies located in the very anthropogenic landscapes of the British Isles and continental Europe (Rotherham

and Lambert 2011). In this book, in contrast with McNeely, and harking back to the dominant ecological literature, there is no content or discussion of cities and urban areas in particular or of urban invasions as a particular concept; the urban is just a location where the topic of introduced and invasive species is discussed in terms of other issues, such as gardening, eradication, management, introduction points, or conflicts.⁴ The opening chapters provide some contextual definitions that indeed would seem to *exclude* the urban from consideration. Ian Rotherham and Robert Lambert (p. 4) state that “for most invasive exotic or alien species a key factor is that they occur ‘in the wild’”. While they then question what “in the wild” might mean, it is clearly far from urban. And Jeffrey McNeely (p. 20) delimits the topic of the book using the GISP definition of invasive alien species, “the subset of alien species whose establishment and spread threatens ecosystems, habitats or species with economic or environmental harm”. The urban is implicitly excluded from this definition. The closest the book comes to dealing with the urban as a concept is in the chapter by historian Chris Smout, where he describes the new “urban ecosystems” (p. 57) created by trade, gardens, and exotics.

Social science and humanities scholarly works engaging with invasive species diverge in their treatment of the urban. For instance, Dobson et al.’s (2013) collection on biosecurity or Frawley and McCalman’s (2014) collection on environmental humanities take no particular interest in urban questions, whereas Biehler (2013)’s *Pests in the City* addresses issues of social justice, urban reform, and environmental planning in cities through the examples of cockroaches, rats, and more. Likewise, Nagy and Johnson (2013)’s *Trash Animals* consecrates a whole section to essays that “reveal the irony inherent when the biological success of some species would have never been possible without the city” (p. 17). It would be safe to say, however, that despite McNeely’s prescient lines, much social science and humanities work on invasive species has mirrored more ecological work in not addressing the urban aspect head on – it is telling that the two counter examples above are more about household pests and pigeons than classical examples of ‘invasive species’. As we will see in the next section, it is more through the growing field of ‘urban ecology’ that both ecologists and social scientists have begun to address the invasive question through an urban lens.

4. THE URBAN TURN IN ECOLOGY

Representations of the ‘urban’ in ecology have changed over time, cities have grown in their global importance, and social and humanities scholars of the city have taken an interest in the nature in their midst. One could say that there is now an interest in, an indulgence for, benevolence towards, or even sympathy for the urban question in ecology: cities used to be considered as a problem, now there is problem in the city. That is, cities used to be external to the main trend in ecology, the antithesis of nature, and hence a blight on the landscape to more ecological worldviews. Current mindsets seem to have adjusted somewhat to accepting cities as fascinating and important (socio-) ecological phenomenon, and recognizing that

⁴ The relatively detailed 9-page index does not include the words ‘urban’, ‘town’, or ‘city’; the only relevant entries are ‘botanic gardens’ (as points of introduction), ‘Chicago’ (as a site for value conflicts), and ‘Wembley Stadium’ (as a case of expensive weed removal costs).

there are problems in the city (such as invasives) that need to be addressed for environmental, economic, health, and cultural reasons.

Here, we investigate what might be called the ‘urban turn’ in mainstream ecology, as opposed to ‘urban ecology’ subfield already mentioned above (in the following section we focus our attention specifically on the urban turn in invasion studies). We first document the turn, then analyse the ideas and sensibilities behind this turn, and finally its implications.

Towards urban ecology

Since roughly the turn of the century an increasing number of studies have considered urban ecosystems. According to Wu (Wu 2014), we are witnessing the burgeoning of a “golden age of urban ecology” in view of the enormous expansion of publications on the subject. For some authors, urban ecology has become part of the mainstream in ecology (McDonnell 2015). According to its proponents, urban ecology is potentially becoming an holistic, integrated science of urban systems (McPhearson et al. 2016), called “ecology **for** the city” (Childers et al. 2015). Urban ecology is viewed by some as an “amalgamation” of several disciplines integrating concepts, terminologies, methods and analytical frameworks from biological, physical and engineering sciences but also social sciences (Douglas 2016). However, as we noted in Section 3 with our discussion of the Berlin school, some ecology has been urban all along; this urban turn is thus mostly relevant for the dominant Anglophone literature.⁵

What lies behind the urban turn

The recent urban turn in ecology reflects a loosening of the ‘blind spot’ identified in section 2. Romantic notions of pristine wilderness – still important rhetorically but thoroughly deconstructed by social scientists (Cronon 1992) – have been supplemented with celebrations of “ragamuffin” or “half wild rambunctious” nature (Marris 2009, 2011) or a scientific interest in “novel” or “emerging” ecosystems (Hobbs et al. 2006, 2013). This was made possible by the field of ecology’s move towards non-equilibrium analytical frameworks (Wallington et al. 2005), in which change and contingency – rather than stability – are regarded as the norm. Disturbances, such as human influences, are considered as internal components of the system rather than external factors (Head 2007).

The rise of new concepts in the past decade or two – from ‘ecosystem services’ to the ‘Anthropocene’ – have also contributed to an openness to consider urban ecologies. As far as ecosystem services, this concept clearly incorporates the role of ecosystems in urban areas, from tree cover attenuating the urban heat island to gardens providing nourishment and recreation. In these cases, it becomes unavoidable to consider the role of omnipresent non-native species in contributing to ecosystem services, social benefits, and possibly to biodiversity conservation (Kowarik 2011; Sjöman et al. 2016). Invasive species might contribute to such

⁵ To identify the beginnings of an American turn towards the urban, one can point to the two Long-Term Ecological Research (LTER) projects supported by the US National Science Foundation – the Baltimore Ecosystem Study and the Central Arizona-Phoenix Long-term Ecological Research. These projects, established in the 1980s, have thirty years of experience in bringing ecology to urban areas, and placing ‘natural’ ecology in dialogue with fields like social ecology (Pickett et al. 2008; Grimm et al. 2013).

services, but also to dis-services (Shackleton et al. 2016; Vas et al. 2017). In a similar vein, the Anthropocene concept invites researchers to place human-modified environments as the starting point of their research. Cities, as anthropogenic environments *par excellence*, merit investigation not only because of the starkness of their case – as Ellis (2016)⁶ writes, “Urban landscapes are the biodiversity melting pots of the Anthropocene” – but they might also be the cradle for finding solutions.

Finally, the growth of urban ecology is linked to a growing recognition of the importance of urban processes and related environmental challenges in a predominantly urban world (McDonnell and Pickett 1993; McDonnell 2015). Global sustainability depends critically on cities, and for some authors, urban ecology can – and needs to – play a key role in the transition toward sustainability (Tanner et al. 2014). Acceptance of these challenges required recognition that the tools of standard, nature-oriented ecology were probably not sufficient. As Pataki (2015) notes,

“While ecology has a century-long history of theorizing the processes that lead to the assembly and function of nonhuman-dominated ecosystems, the extent to which such theories can be applied to designed and constructed ecosystems is still actively debated” (p. 2).

Instead, urban ecology encountered an urgent need to understand how urban systems work and how they ought to work, questions that are central to the field of planning (Alberti 2009).

The implications of urban ecology

The study of urban ecosystems shows with no surprise that cities can be hostile to nature. Cities are synonymous with pollution, homogenisation, mineralization, human disturbances, habitat fragmentation, and pressure of alien species. But urban ecology has sometimes offered counterintuitive results. For instance, it established positive correlations between habitat variability in cities and plant species richness (Niemelä 1999), although human management regimes may be a stronger factor (Pickett et al. 2001). It has highlighted cases of higher species richness for both native and non-native species in urban areas than in countryside areas (Kühn et al. 2004; Wania, A. et al. 2006; Fontana et al. 2011). Urban ecology also demonstrates the importance of some urban areas to biodiversity conservation. For instance, urban areas can serve as refugia for species endangered by intensive agriculture (Pyšek 1998; Ives et al. 2016). Likewise, private backyards have been shown to be crucial to wildlife habitat (Savard et al. 2000).

In summary, while urban ecology obviously does not deny the often-deleterious impacts of urban activities on ecosystems, the field distances itself from a conception of the city as exclusively harmful to nature. It offers a renewed vision of the relations between human activities and the ‘natural’ environment in urban areas. However, it would be wrong to believe that the values of urban ecology are representative across the entire field of ecology. The value of conserving urban biodiversity remains controversial. The urban realm always seems to be a less appropriate location for actions regarding biological conservation (Miller and

⁶ <https://ugecviewpoints.wordpress.com/2016/06/07/cultures-of-nature-what-does-it-mean-to-be-native-in-the-city/> (last consulted 1.08.2017)

Hobbs 2002; Salomon Cavin 2013). Yet, ‘urban ecology’ has gone beyond the frontiers of scientific ecology and become a kind of boundary object (Star and Griesemer 1989) that succeeds in bringing together scholars across the arts and sciences with concern for ‘nature’ in urban places. Topics that bring together diverse scholars under the banner of urban ecology include urban parks and gardens, urban water cycles, and, of course, invasive species and other ‘wildlife’ in the city – as shown by Dion and Rockman’s (1996) edited volume titled *Concrete Jungle*.

5. AN INTEREST IN ‘URBAN INVASIONS’

While ecologists, city landscapers, pest control departments, and backyard gardeners have always been interested in new plants, animals, and insects spreading in – and causing problems in – cities, the framing of the issue as ‘urban invasions’ or ‘biological invasions in urban environments’ is relatively new in invasion biology. Indeed, the scientific literature on the topic (framed in this way) appears later than that on urban ecology – the four articles cited in our opening paragraph all date from the 2010s. Perhaps this has something to do with the ambivalence or disregard of earlier invasion biology for the urban, as we documented above, and more profoundly because a turn to highly anthropogenic environments troubles some of the central concepts of invasion biology. We will return to this in the discussion below. In this section, we seek instead to further prepare the ground for this discussion by categorizing the different types of social representations or discourses relevant to ‘urban invasions’.

Table 1 summarizes three main discourses found in discussions of urban invasions. The discourses are necessarily archetypal; in reality they are not exclusive and can co-exist. The first discourse frames cities as a problem. This has largely been the dominant discourse in invasion science. In addition, now there are additional discourses that see cities as victims and as solutions because policies need to be implemented within the cities and by local authorities.

| How cities are seen in (urban) invasions | Role of invasive species in the discourse | Representation of urban nature in the discourse | Key articles in this special issue illustrative of this discourse |
|------------------------------------------------|----------------------------------------------------------------------------|-------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| Cities as problem | Cities are entry point and place of spread for invasive species | Degraded, degenerate | (Hulbert et al. 2017; Mayer et al. 2017; McLean et al. 2017; Paap et al. 2017; Padayachee et al. 2017) |
| Cities as victim | Urban biodiversity, human population, infrastructure suffer from invasives | Intrinsic worth | (Potgieter et al. 2017) |
| Cities as actors and potential solution | Invasive species have to be tackled in the city | Intrinsic worth | (Gaertner 2017; Walker 2017) |

Table 1: Archetypal discourses about cities and urban nature in invasion science.

These archetypal discourses are well demonstrated in the recent IUCN report titled *Invasive alien species: the urban dimension* (van Ham et al. 2013). In their preface, Riccardo Scalera and Piero Genovesi identify the city as crucial to understanding and manage biological invasions first because they are hotspots of invasion (hence, ‘cities as problem’) but also because

“urban environments in many cases host an important proportion of the overall biodiversity, and as a result, invasive alien species represent a serious threat to the native wildlife in urbanised areas, that are often already under ‘siege’” (p. 8)

This follows the discourse of ‘cities as victims’, under which the authors recognize a key role for urban areas regarding biodiversity. Finally, they cite the role of city-based conservation institutions and local administrators in leading efforts in fundraising, awareness-building, and action (hence, ‘cities as an actor’). Below we review some of the key elements or examples of these three discourses.

The discourse of “Cities as problem”

Cities are seen as problematic in terms of biological invasions in several ways. First of all, they serve as points of entry, beachheads, or gateway nodes through which non-native species arrive into a new region. This involves not only ports and airports, but also specifically botanical gardens, horticultural industries (Hulme 2011; Humair et al. 2015), and pet shops. Urban areas are particularly prone to plant invasions (Trepl 1995; Pyšek 1998): many exotic plants are deliberately introduced for ornamental purposes (Reichard and White 2001; van Ham et al. 2013) and urban areas are focal points for trade and transport (roads, railways and waterways, harbours and airports), which convey many exotic plant species and maintain a high level of propagule pressure (Vilà and Pujadas 2001; McKinney 2004; von der Lippe and Kowarik 2007; Maurel et al. 2010). Urban areas are also often highly “invasible”, with many disturbed or degraded environments prone to invasion. Thus they can form places of spread, or concentration of invasive species.

The discourse of “Cities as victim”

Recently, another discourse has emerged, one that sees the city as victim of invasives. In this representation, cities are not considered as problem *per se*, but there are problems in the city (such as invasives) that need to be addressed for environmental, economic, health, and cultural reasons. The idea is well illustrated the title of a piece by Gaertner et al. (2015) “Cities invaded”. Instead of qualifying invasions as urban, cities are actively invaded, suggesting that cities suffer. The negative impacts of invasive species in cities include health, infrastructure, security, and biodiversity.

First, some invasive species are particularly problematic for health reasons. For instance, it is often pointed out that the major impact of giant hogweed (*Heracleum mantegazzianum*) is on human health. Photosensitive metabolites on human skin react under ultraviolet radiation (sunlight) with a burning sensation reaction that can cause serious skin lesions (Probert et al. 2013). Likewise, ragweed (*Ambrosia artemisiifolia*) is one of the most pollen-allergenic plants, representing a serious health risk for humans (e.g Smith et al. 2013). The pollen of this North American native is a potent trigger of hay fever, with financial impacts of its spread in diverse European countries calculated in the billions (Kettunen et al. 2009; Kull and Rangan 2015).

Second, invasives can damage urban infrastructures and landscapes. In the UK, the Japanese knotweed (*Fallopia japonica*) is famous for its ability to devalue the built environment. Reputed as a “concrete cracking superweed”, it causes many costly problems in the buildings both structurally and aesthetically (Djeddour and Shaw 2010). Another infamous case is that of a feral population of rabbits in Helsinki. Once this population, descended from pets dumped in the wild, became established in a sandy-soiled graveyard, it caused trees and even tombstones to fall (van Ham et al. 2013).

Third, another perceived impact of invasive species in urban areas is increased risk. Such risk takes many forms, from increased fire activity (e.g. the fire threat from invasive broom and gorse in suburban California (Lambert et al. 2010) to physical insecurity. In Cape Town, not only do invasive pines and wattles increase wildfire severity near residential areas, they are also frequently cited as unwelcome hiding places for criminals (Gaertner et al. 2015).

Finally, urban invasions impact urban biodiversity. Invasive species can threaten native species already struggling because of the presence of cities. Alternatively, invasions can threaten the novel ecosystems as well as anthropogenic plantings that have become to be valued in many urban areas (Shochat et al. 2010; Zisenis 2015).

The discourse of ‘cities as actors’

With all the attention given to cities and urban issues in recent years (even more notable in 2016 during the UN’s Habitat III conference, which, for instance, inspired a special issue of the journal *Nature*), it is clear that cities are increasingly seen as key actors to tackle the problem of biological invasions. Cities – at least the people living in them, the organisations based in them, and the structures of government and management of the urban areas – are sources of potential solutions. The well-being and attitudes of the urban populace play a major role in affecting policies and actions in urban areas and beyond; municipal administrations are typically at the front lines for implementing relevant policies. Finally, urban stakeholders play a key role in tackling the problem of invasive species notably by making citizens aware of the importance of biodiversity and promoting the implementation of dedicated actions by the relevant administration (van Ham et al. 2013).

6. DISCUSSION

We have shown that there has been a perceptible move – though not linear, and far from universal – from considering “the urban” as irrelevant in the modern field of invasion biology, to a sympathy and concern for the urban. We have shown that this reflects, to some degree, a similar move in modern ecology in general – from the urban as un-natural, to the urban as interesting. Yet what makes invasion biology somewhat different from mainstream ecology is that the “human” is involved *by definition*. By definition, invasive species must have been helped across biogeographic barriers by humans (Richardson et al. 2000), or they must have negative impacts on native biodiversity or human endeavours (McNeely

2001). Such conceptions echo the words of weed scientists Harlan and de Wet (1965: 19) : “there were no weeds before man”.

However, the strong influence of mainstream ecology on the emerging field of invasion biology in the 1980s and 1990s meant that it perhaps did not fully consider the ‘human’ aspect. The urban turn that we document is perhaps finally the chance for invasion biology to more explicitly consider the ‘human’ aspect – for ‘the urban’ (defined as a dense concentration of humans) is the quintessential manifestation of ‘the human’. Taking this further, there are ways in which the idea of urban invasions contributes to rethinking some central concepts in ecology and invasion science. While ecology has a long tradition of studying ‘pure’ nature, invasion ecology focuses on what might in contrast be painted as ‘degenerate’ nature. From this traditional perspective, cities are one of the worst cases of this degenerate nature.

The turn to cities in invasion biology makes much more obvious the discordance inherent in visions of pure nature inherited from general ecology and biological conservation. If one moves to protecting urban areas and their anthropogenic natures from invasives (who arrive because of people, intentionally or accidentally, or perhaps on their own), then there are consequences for some of the central concepts in invasion science. **First**, the distinction between *native* and *alien* no longer helps to distinguish between what must be protected and what must be avoided. If new ecological perspectives accept or even celebrate anthropogenic species assemblages or novel ecosystems, such as those found in some urban environments, then should urban environmental managers accept newly introduced alien species, even invasive ones, as potential contributors to these novel ecosystems? Since built-up and settled areas are rarely ‘natural’ and ‘native’⁷, urban environmental management questions render much more explicit the judgements necessary when simple dichotomies like native and alien do not suffice. For this reason, perhaps, (Dunnett and Hitchmough 2007) pose an important question:

“Some ecologists and conservationists persist in seeing urban ecology as dealing with native species that survive plus alien species and in doing suggest that urban species essentially form degenerate version of adjacent rural ecosystems. Others like (Mcintyre et al. 2000) see the Anthropogenic jumble of urban plan assemblages as being of intrinsic worth: Why should for example nature like plant communities brought into effect by intentional (or non-intentional) human agency be ecologically and aesthetically intrinsically less valuable than those that result from random combination of chance event?” (p. 13).

We suggest that from an urban ecology perspective, such nature is not intrinsically less valuable, but that for humans it can be judged as harmful, destructive, problematic, or beautiful, or helpful, based on a variety of social, economic, and cultural criteria.

⁷ It should be noted that endemic species do exist in a number of built-up urban areas. Furthermore, several cities have ‘natural’ sites within city limits, due to topographic or political controls on urban spread that pose interesting definitional limits to what qualifies as urban. Cape Town is an exemplary example (Rebelo et al. 2011).

Second, a focus on urban invasions gives a different credence to the question of *impact*. Addressing urban invasions forces analysts to broaden their gaze from the narrow impacts of invaders on the functioning or diversity of an intact native ecosystem to broader impacts on urban infrastructures, human populations, culture, economy, and urban non-human species assemblages (see Blackburn et al. 2014)). And with these broad categories come the associated questions of who gains, who loses, and who decides which impacts are more important.

Third, a focus on urban invasions serves to emphasize the human role in invasions, as opposed to invasion biology perspectives that implicitly blames the plant or animal species. Cities, as we note earlier, are key nodes in the *dispersal pathways* of many invaders. Human *disturbance* plays a key role in the *invasibility* of many urban environments, from empty lots to road verges. These roles are implicit in much invasion science, but an urban focus makes them much more visible and explicit.

These observations all suggest more explicit and direct attention to human roles and judgements. In a way, this would reverse the swing of the pendulum. The field might come full circle, from historical concerns with pests and weeds troubling humans in their homes and fields, to worries over invasives in wild nature, and back to an interest in plants and animals because they are a problem for us. The advantage of interest in ‘pests and weeds’ is that they refocus attention on us humans and our role in moving them, our role in creating the ecological conditions for their invasive behaviour, and our role in labelling them as noxious or problematic (Harlan and de Wet (1965)).

A transition to a more anthropocentric, or relational conceptions of nature (Chan et al. 2016) is probably timely in invasion ecology. Much of the recent questioning of invasion ecology (Davis et al. 2011; Marris 2011; Richardson and Ricciardi 2013; Tassin and Kull 2015) centres on problems with the field’s overreliance on dichotomies like alien/native, natural/anthropogenic, being theoretically too focused on human-introduced plants and animals in ‘natural’ nature, and not coming to terms with the recombinant and novel ecosystems of the Anthropocene. One could suppose that as the field has incorporated such critiques, this process has opened the door to the field taking an interest in invasive ecologies in the most human-modified of all ecosystems: the city.

7. REFERENCES

- Alberti M (2009) *Advances in urban ecology: integrating humans and ecological processes in urban ecosystems*. Springer, New York
- Baker H, Stebbins GL (1965) *The genetics of colonizing species: proceedings*. Academic Press, New York and London
- Biehler DD (2013) *Pests in the City: Flies, Bedbugs, Cockroaches, and Rats*. University of Washington Press, Seattle

- Blackburn TM, Essl F, Evans T, et al (2014) A Unified Classification of Alien Species Based on the Magnitude of their Environmental Impacts. *PLOS Biol* 12:e1001850. doi: 10.1371/journal.pbio.1001850
- Bornkamm R (1975) Some observations on weed communities in the city of Durham, North Carolina, USA. *Beitr Naturk ForschSüdw* 15–24
- Braun-Blanquet J (1932) *Plant sociology; the study of plant communities* (authorized English translation of *Pflanzensoziologie*, by Dr. J. Braun-Blanquet. Translated, revised and edited by George D. Fuller and Henry S. Conard), 1st ed. McGraw-Hill book company, inc., New York and London
- Bridgewater PB, Backshall DJ (1979) Changes induced by adventive species in Australian plant communities. In: Wilmanns O, Tüxen R (eds) *Werden und Vergehen von Pflanzengesellschaften. Berichte der Internationalen Symposien der Internationalen Vereinigung für Vegetationskunde* (Rinteln, 20-23 March 1978), J. Cramer Vaduz. pp 561–579
- Broto VC, Allen A, Rapoport E (2012) Interdisciplinary Perspectives on Urban Metabolism. *J Ind Ecol* 16:851–861. doi: 10.1111/j.1530-9290.2012.00556.x
- Chan KMA, Balvanera P, Benessaiah K, et al (2016) Opinion: Why protect nature? Rethinking values and the environment. *Proc Natl Acad Sci* 113:1462–1465
- Chew M (2006) *Ending with Elton: Preludes to Invasion Biology*. Arizona State University
- Chew M (2011) *Invasion Biology: Historical Precedents*. In: Simberloff D, Rejmánek M (eds) *Encyclopedia of biological Invasions*. University of California Press, Berkeley and Los Angeles, pp 369–375
- Chew MK, Hamilton AL (2011) The rise and fall of biotic nativeness: a historical perspective. In: Richardson DM (ed) *50 Years of Invasion Ecology: the Legacy of Charles Elton*. Blackwell, London
- Childers DL, Cadenasso ML, Grove JM, et al (2015) An Ecology for Cities: A Transformational Nexus of Design and Ecology to Advance Climate Change Resilience and Urban Sustainability. *Sustainability* 7:3774–3791. doi: 10.3390/su7043774
- Clergeau P (2010) *Ecologie urbaine et biodiversité*. In: Coutard O, Lévy J-P (eds) *Ecologies Urbaines*. Economica, Paris, pp 154–165
- Corbyn Z (2010) Ecologists shun the urban jungle. *Nature*. doi: 10.1038/news.2010.359

- Cronk QCB, Fuller JL (1995) *Plant Invaders: the Threat to Natural Ecosystems*. Chapman & Hall, London
- Cronon W (1992) *Nature's metropolis: Chicago and the Great West*. WWNorton & Co, New York
- Ćwikliński E (1971) Flora synantropijna Szczecina (the synanthropic flora of Szczecin). *Monog Bot* 5–103
- Davis M (2002) *Dead cities: and other tales*. The New Press, New York
- Davis MA (2009) *Invasion Biology*. Oxford University Press, Oxford
- Davis MA, Chew MK, Hobbs RJ, et al (2011) Don't judge species on their origins. *Nature* 474:153–154
- De-Shalit A (2003) Philosophy Gone Urban: Reflections on Urban Restoration. *J Soc Philos* 34:6–27. doi: 10.1111/1467-9833.t01-1-00162
- Dion M, Rockman A (1996) *Concrete Jungle: A Pop Media Investigation of Death and Survival in Urban Ecosystems*. Juno Books, New York
- Djeddour DH, Shaw RH (2010) The Biological Control of *Fallopia Japonica* in Great Britain: Review and Current Status. *Outlooks Pest Manag* 21:15–18. doi: 10.1564/21feb04
- Dobson A, Barker K, Taylor SL (eds) (2013) *Biosecurity: the Socio-Politics of Invasive Species and Infectious Diseases*. Routledge-Earthscan, London
- Douglas I (2017) Urban Ecology. In: Richardson D, Castree N, Goodchild M, et al. (eds) *The International Encyclopedia of Geography*. John Wiley & Sons, Ltd
- Douglas I (ed) (2016) *Urban ecology: critical concepts in geography*. Routledge, Abingdon
- Drake JA, Mooney HA, di Castri F, et al (eds) (1989) *Biological Invasions: A Global Perspective*. John Wiley & Sons, Chichester
- Dunnett N, Hitchmough J (2007) *The Dynamic Landscape: Design, Ecology and Management of Naturalistic Urban Planting*. Taylor & Francis, London
- Elton C (1958) *The Ecology of Invasions by Animals and Plants*, The University of Chicago Press. Chicago and London
- Faliński JB (1971) Synanthropisation of plant cover. II. Synanthropic flora and vegetation of towns connected with their natural conditions, history and function. *Mater Zasl Fitosoc Stosow* 1–317

- Fontana S, Sattler T, Bontadina F, Moretti M (2011) How to manage the urban green to improve bird diversity and community structure. *Landsc Urban Plan* 101:278–285. doi: 10.1016/j.landurbplan.2011.02.033
- Francis RA, Chadwick MA (2015) Urban invasions: non-native and invasive species in cities. *Geography* 100:144
- Francis RA, Lorimer J, Raco M (2013) What is special about urban ecologies? *Trans Inst Br Geogr* 38:682–684. doi: 10.1111/tran.12037
- Frawley J, McCalman I (eds) (2014) *Rethinking Invasion Ecologies from the Environmental Humanities*. Routledge, London
- Gaertner M (2017) Managing invasive species in cities: A decision support framework applied to Cape Town. *Biol Invasions*. doi: 10.1007/s10530-017-1587-x
- Gaertner M, Irlich U, Visser V, et al (2015) Cities invaded. *Quest* 11:48–50
- Gilbert OL (1989) *The Ecology of Urban Habitats*. Springer Netherlands, Dordrecht
- Grimm NB, Grove JG, Pickett STA, Redman CL (2000) Integrated Approaches to Long-Term Studies of Urban Ecological Systems. *BioScience* 50:571–584. doi: 10.1641/0006-3568(2000)050[0571:IATLTO]2.0.CO;2
- Grimm NB, Redman CL, Boone CG, et al (2013) Viewing the Urban Socio-ecological System Through a Sustainability Lens: Lessons and Prospects from the Central Arizona–Phoenix LTER Programme. In: Singh S, Haberl H, Chertow M, et al. (eds) *Long Term Socio-Ecological Research. Human-Environment Interactions*. Springer, Dordrecht, pp 217–246
- Gunn AS (1998) Rethinking Communities: Environmental Ethics in an Urbanized World. *Environ Ethics* 20:341–360
- Harlan JR, de Wet JMJ (1965) Some thoughts about weeds. *Econ Bot* 19:16–24
- Harlan JR, de Wet JMJ (1975) Weeds and domesticates: evolution in the man-made habitat. *Econ Bot* 99–107
- Head L (2007) Cultural ecology: the problematic human and the terms of engagement. *Prog Hum Geogr* 31:837–846. doi: 10.1177/0309132507080625
- Head L, Muir P (2006) Edges of Connection: reconceptualising the human role in urban biogeography. *Aust Geogr* 37:87–101. doi: 10.1080/00049180500511996

- Hobbs RJ, Arico S, Aronson J, et al (2006) Novel ecosystems: theoretical and management aspects of the new ecological world order. *Glob Ecol Biogeogr* 15:1–7. doi: 10.1111/j.1466-822X.2006.00212.x
- Hobbs RJ, Higgs ES, Hall C (eds) (2013) *Novel Ecosystems: Intervening in the New Ecological World Order*. Wiley, Oxford
- Hobbs RJ, Richardson DM (2011) Invasion ecology and restoration ecology: Parallel evolution in two fields of endeavour. In: Richardson DM (ed) *Fifty years of invasion ecology. The legacy of Charles Elton*, Wiley-Blackwell. Oxford, pp 61–69
- Hulbert JM, Agne MC, Burgess TI, et al (2017) Urban environments provide opportunities for early detections of *Phytophthora* invasions. *Biol Invasions* 19:3629–3644. doi: 10.1007/s10530-017-1585-z
- Hulme PE (2011) Addressing the threat to biodiversity from botanic gardens. *Trends Ecol Evol* 26:168–174. doi: 10.1016/j.tree.2011.01.005
- Humair F, Humair L, Kuhn F, Kueffer C (2015) E-commerce trade in invasive plants. *Conserv Biol* 29:1658–1665. doi: 10.1111/cobi.12579
- Ives CD, Lentini PE, Threlfall CG, et al (2016) Cities are hotspots for threatened species. *Glob Ecol Biogeogr* 25:117–126. doi: 10.1111/geb.12404
- Joyal R (1970) La Flore vasculaire de l'Île des Soeurs. *Nat Can* 559–583
- Kettunen M, Genovesi, Piero, Gollasch S, et al (2009) *Technical Support to EU Strategy on Invasive Species (IAS): Assessment of the Impacts of IAS in Europe and the EU. Final module report for the European Commission*. Institute for European Environmental Policy, Brussels
- Kowarik I (2013) *Cities and Wilderness. A New Perspective*. *Int J Wilderness* 19:31–36
- Kowarik I (2011) Novel urban ecosystems, biodiversity, and conservation. *Environ Pollut* 159:1974–1983. doi: 10.1016/j.envpol.2011.02.022
- Kowarik I, Pyšek P (2012) The first steps towards unifying concepts in invasion ecology were made one hundred years ago: revisiting the work of the Swiss botanist Albert Thellung. *Divers Distrib* 18:1243–1252. doi: 10.1111/ddi.12009
- Kueffer C, Hadorn GH (2008) How to Achieve Effectiveness in Problem-Oriented Landscape Research: The Example of Research on Biotic Invasions. *Living Rev Landsc Res* 2:. doi: 10.12942/lrlr-2008-2

- Kühn I, Brandl R, Klotz S (2004) The flora of German cities is naturally species rich. *Evol Ecol Res* 6:749–764.
- Kull C, Rangan H (2015) The political ecology of weeds: a scalar approach to landscape transformation. In: Bryant R (ed) *The International Handbook of Political Ecology*, Edward Elgar. Cheltenham, pp 487–500
- Kull CA, Arnaud de Sartre X, Castro-Larrañaga M (2015) The political ecology of ecosystem services. *Geoforum* 61:122–134
- Lachmund J (2012) *Greening Berlin: The Co-Production of Science, Politics, and Urban Nature*. The MIT Press, Cambridge Mass.
- Lachmund J (2007) Ecology in a walled city: researching urban wildlife in post-war Berlin. *Endeavour* 31:78–82. doi: 10.1016/j.endeavour.2007.05.001
- Lambert RA, D'Antonio CM, Dudley TL (2010) Lambert, AM, C D'Antonio & TL Dudley (2010) Invasive species and fire in California ecosystems. *38 (2-3):29-36. Fremontia* 38:29–36
- Light A (2001) The Urban Blind Spot in Environmental Ethics. *Environ Polit* 10:7–35. doi: 10.1080/714000511
- Lockwood JL (2007) *Invasion ecology*. Blackwell, Malden
- Marris E (2011) *The Rambunctious Garden: Saving Nature in a Post-Wild World*, Reprint edition. Bloomsbury USA
- Marris E (2009) Ecology: Ragamuffin Earth. *Nat News* 460:450–453. doi: 10.1038/460450a
- Marris E, Mascaro J, Ellis EC (2013) Perspective: Is Everything a Novel Ecosystem? If so, do we need the Concept? In: Hobbs RJ, Higgs ES, Hall CM (eds) *Novel Ecosystems: Intervening in the New Ecological World Order*. John Wiley & Sons, Ltd, Chichester, UK, pp 345–349
- Martin LJ, Blossey B, Ellis E (2012) Mapping where ecologists work: biases in the global distribution of terrestrial ecological observations. *Front Ecol Environ* 10:195–201. doi: 10.1890/110154
- Maurel N, Salmon S, Ponge J-F, et al (2010) Does the invasive species *Reynoutria japonica* have an impact on soil and flora in urban wastelands? *Biol Invasions* 12:1709–1719. doi: 10.1007/s10530-009-9583-4
- Mayer K, Haeuser E, Dawson W, et al (2017) Naturalization of ornamental plant species in public green spaces and private gardens. *Biol Invasions* 19:3613–3627. doi: 10.1007/s10530-017-1594-y

- McDonnell MJ (1997) A Paradigm Shift. *Urban Ecosyst* 1:85–86. doi: 10.1023/A:1018598708346
- McDonnell MJ (2015) *Journal of Urban Ecology: Linking and promoting research and practice in the evolving discipline of urban ecology.* *J Urban Ecol* 1:juv003. doi: 10.1093/jue/juv003
- McDonnell MJ, Pickett STA (1990) Ecosystem Structure and Function along Urban-Rural Gradients: An Unexploited Opportunity for Ecology. *Ecology* 71:1232–1237. doi: 10.2307/1938259
- McDonnell MJ, Pickett STA (eds) (1993) *Humans as Components of Ecosystems.* Springer New York, New York
- Mcintyre NE, Knowles-Yáñez K, Hope D (2000) Urban ecology as an interdisciplinary field: differences in the use of “urban” between the social and natural sciences. *Urban Ecosyst* 4:5–24. doi: 10.1023/A:1009540018553
- McKinney ML (2004) Citizens as Propagules for Exotic Plants: Measurement and Management Implications. *Weed Technol* 18:1480–1483
- McLean P, Gallien L, Wilson JRU, et al (2017) Small urban centres as launching sites for plant invasions in natural areas: insights from South Africa. *Biol Invasions* 19:3541–3555. doi: 10.1007/s10530-017-1600-4
- McNeely JA (ed) (2001) *The Great Reshuffling: Human Dimensions of Invasive Alien Species.* IUCN, Gland
- McPhearson T, Pickett STA, Grimm NB, et al (2016) Advancing Urban Ecology toward a Science of Cities. *BioScience* 66:198–212. doi: 10.1093/biosci/biw002
- MEA (2005) *Ecosystems and Human Well-being: Synthesis.* Island Press, Washington DC.
- Melosi MV (1993) The Place of the City in Environmental History. *Environ Hist Rev* 17:1–23. doi: 10.2307/3984888
- Miller J, Hobbs R (2002) Conservation where people live and work. *Conserv Biol* 16:330–337
- Mitman G (2004) When pollen became poison: a cultural geography of ragweed in America. In: Daston L, Vidal F (eds) *Moral Authority of Nature.* University of Chicago Press, Chicago, pp 438–65
- Müller P (1970) Durch den Menschen bedingte Arealveränderung brasilianischer Wirbeltiere. *Nat Mus* 22–37

- Myers JH, Bazely DR (2003) *Ecology and Control of Introduced Plants*. Cambridge University Press, Cambridge
- Nagy K, Johnson PD II (eds) (2013) *Trash Animals: How We Live with Nature's Filthy, Feral, Invasive, and Unwanted Species*. University of Minnesota Press, Minneapolis
- Niemelä J (1999) Ecology and urban planning. *Biodivers Conserv* 8:119–131. doi: 10.1023/A:1008817325994
- Odum EP (1959) *Fundamentals of ecology*, Saunders. Philadelphia,
- Paap T, Burgess TI, Wingfield MJ (2017) Urban trees: bridge-heads for forest pest invasions and sentinels for early detection. *Biol Invasions* 19:3515–3526. doi: 10.1007/s10530-017-1595-x
- Padayachee AL, Irlich UM, Faulkner KT, et al (2017) How do invasive species travel to and through urban environments? *Biol Invasions* 19:3557–3570. doi: 10.1007/s10530-017-1596-9
- Pataki DE (2015) Grand challenges in urban ecology. *Front Ecol Evol* 3:. doi: 10.3389/fevo.2015.00057
- Pickett, M. L. Cadenasso, J. M. Grove, et al (2001) Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas. *Annu Rev Ecol Syst* 32:127–157. doi: 10.1146/annurev.ecolsys.32.081501.114012
- Pickett STA, Cadenasso ML, Grove JM, et al (2008) Beyond Urban Legends: An Emerging Framework of Urban Ecology, as Illustrated by the Baltimore Ecosystem Study. *BioScience* 58:139–150. doi: 10.1641/B580208
- Potgieter LJ, Gaertner M, Kueffer C, et al (2017) Alien plants as mediators of ecosystem services and disservices in urban systems: a global review. *Biol Invasions* 19:3571–3588. doi: 10.1007/s10530-017-1589-8
- Probert SM, Lacey J, Gautam S (2013) Giant Hogweed burns. *Arch Dis Child archdischild-2012-303229*. doi: 10.1136/archdischild-2012-303229
- Pyšek P (1995) Approaches to studying spontaneous settlement flora and vegetation in central Europe: a review. In: Sukopp H, Numata M, Huber A (eds) *Urban Ecology as the Basis of Urban Planning*, SPB Academic Publishing. Amsterdam, pp 23–39
- Pyšek P (1998) Alien and native species in Central European urban floras: a quantitative comparison. *J Biogeogr* 25:155–163. doi: 10.1046/j.1365-2699.1998.251177.x

- Pyšek P, Jarošík V, Kadlec T (2011) Alien plants in urban nature reserves: from red-list species to future invaders? *NeoBiota* 10, 10:27–46. doi: 10.3897/neobiota.10.1262
- Reichard SH, White P (2001) Horticulture as a Pathway of Invasive Plant Introductions in the United States. *BioScience* 51:103–113. doi: 10.1641/0006-3568(2001)051[0103:HAAPOI]2.0.CO;2
- Richardson DM (ed) (2011) Fifty years on invasion ecology: the legacy of Charles Elton. Wiley-Blackwell, Chichester
- Richardson DM, Pyšek P (2008) Fifty years of invasion ecology – the legacy of Charles Elton. *Divers Distrib* 14:161–168
- Richardson DM, Pyšek P, Rejmánek M, et al (2000) Naturalization and invasion of alien plants: concepts and definitions. *Divers Distrib* 6:93–107. doi: 10.1046/j.1472-4642.2000.00083.x
- Richardson DM, Ricciardi A (2013) Misleading criticisms of invasion science: a field guide. *Divers Distrib* 19:1461–1467. doi: 10.1111/ddi.12150
- Rotherham ID, Lambert RA (eds) (2011) *Invasive and Introduced Plants and Animals: Human Perceptions, Attitudes and Approaches to Management*. Routledge/Earthscan, London
- Salomon Cavin J (2013) Beyond prejudice: Conservation in the City. A case study from Switzerland. *Biol Conserv* 166:84–89. doi: 10.1016/j.biocon.2013.06.015
- Salomon Cavin J, Marchand B (eds) (2010) *Antiurbain: origines et conséquences de l'urbaphobie*. PPUR, Lausanne
- Savard J-PL, Clergeau P, Mennechez G (2000) Biodiversity concepts and urban ecosystems. *Landsc Urban Plan* 48:131–142. doi: 10.1016/S0169-2046(00)00037-2
- Shackleton CM, Ruwanza S, Sanni GKS, et al (2016) Unpacking Pandora's Box: Understanding and Categorising Ecosystem Disservices for Environmental Management and Human Wellbeing. *Ecosystems* 19:587–600. doi: 10.1007/s10021-015-9952-z
- Shochat E, Lerman SB, Anderies JM, et al (2010) Invasion, Competition, and Biodiversity Loss in Urban Ecosystems. *BioScience* 60:199–208. doi: 10.1525/bio.2010.60.3.6
- Simberloff D (2013) *Invasive Species: What Everyone Needs to Know*. Oxford University Press, Oxford
- Sjöman H, Morgenroth J, Sjöman JD, et al (2016) Diversification of the urban forest—Can we afford to exclude exotic tree species? *Urban For Urban Green* 18:237–241. doi: 10.1016/j.ufug.2016.06.011

- Smith M, Cecchi L, Skjøth CA, et al (2013) Common ragweed: A threat to environmental health in Europe. *Environ Int* 61:115–126. doi: 10.1016/j.envint.2013.08.005
- Star SL, Griesemer JR (1989) Institutional Ecology, 'Translations' and Boundary Objects: Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Soc Stud Sci* 19:387–420. doi: 10.1177/030631289019003001
- Sukopp H (1998) Urban Ecology: Scientific and Practical Aspects. In: Breuste J, Feldmann H, Uhlmann O (eds) *Urban Ecology*, Springer-Verlag. Berlin, pp 3–16
- Sukopp H (2002) On the early history of urban ecology in Europe. *Preslia Praha* 373–393
- Sukopp H (1973) Die Großstadt als Gegenstand ökologischer Forschung. *Forsch – Schr Ver Verbreit Naturwiss Kenntn Wien* 113:90–140
- Sukopp H (1980) *Contributions to Urban Ecology*, Berlin (West), Institut Für ökologie, Technical Univ. Berlin. Berlin
- Tanner CJ, Adler FR, Grimm NB, et al (2014) Urban ecology: advancing science and society. *Front Ecol Environ* 12:574–581. doi: 10.1890/140019
- Tassin J, Kull CA (2015) Facing the broader dimensions of biological invasions. *Land Use Policy* 42:165–169. doi: 10.1016/j.landusepol.2014.07.014
- Tilman D, Fargione J, Wolff B, et al (2001) Forecasting agriculturally driven global environmental change. *Science* 292:281–284. doi: 10.1126/science.1057544
- Timmons FL (1970) A history of weed control in the United States and Canada. *Weed Sci* 18:294–306
- Trepl L (1995) Towards a theory of urban biocenoses. Some hypotheses and research questions. In: Sukopp H, Numata M, Huber A (eds) *Urban ecology as the basis of urban planning*, SPB Academic Publishing. The Hague, pp 3–21
- van Ham C, Genovesi P, Scalera R (2013) *Invasive alien species: the urban dimension. Case studies on strengthening local action in Europe*. IUCN, Brussels
- Vas A, Kueffer C, Kull C, et al (2017) Integrating ecosystem services and disservices: insights from plant invasions. *Ecosyst Serv* 23:94–107

- Vilà M, Pujadas J (2001) Land-use and socio-economic correlates of plant invasions in European and North African countries. *Biol Conserv* 100:397–401. doi: 10.1016/S0006-3207(01)00047-7
- von der Lippe M, Kowarik I (2007) Long-distance dispersal of plants by vehicles as a driver of plant invasions. *Conserv Biol J Soc Conserv Biol* 21:986–996. doi: 10.1111/j.1523-1739.2007.00722.x
- Walbridge MR (1996) Urban Ecosystems. *Urban Ecosyst* 1:1–2. doi: 10.1023/A:1014307007437
- Walker G (2017) The potential range of *Ailanthus altissima* (tree of heaven) in South Africa: the roles of climate, land use and disturbance. *Biol Invasions*
- Wallington TJ, Hobbs RJ, Moore SA (2005) Implications of current ecological thinking for biodiversity conservation: A review of the salient issues. *Ecol Soc* 10:16
- Wania, A., Kuhn, I., Klotz, S. (2006) Plant richness patterns in agricultural and urban landscapes in Central Germany—spatial gradients of species richness. *Landsc Urban Plan* 75:97–110
- Williamson M (1996) *Biological Invasions*. Chapman & Hall, London
- Wittig R (1991) *Ökologie der Großstadtflora*, G. Fischer. Stuttgart
- Wu J (2014) Urban ecology and sustainability: The state-of-the-science and future directions. *Landsc Urban Plan* 125:209–221. doi: 10.1016/j.landurbplan.2014.01.018
- Zimdahl R (2010) *A History of Weed Science in the United States*, Elsevier. London
- Zisenis M (2015) Alien plant species: A real fear for urban ecosystems in Europe? *Urban Ecosyst* 18:355–370. doi: 10.1007/s11252-014-0400-1