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978-0-521-76984-6 - Urban Ecosystems: Ecological Principles for the Built Environment
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Excerpt
More information

1 Urban ecosystems and the science of ecology

Every fall, the weather cools, the days shorten, the soil starts to dry, and leaves drop from deciduous trees in temperate regions. These leaves carpet the ground, changing how nutrients and water infiltrate the soil, determining which plants will grow the following spring, altering the insect community, and changing the very scent of the forest. How long these changes persist depends on the availability of water and warmth, and the properties of the leaves themselves, with some being highly resistant to decomposition and others far less so. Sometimes these changes are beneficial for the tree itself, and sometimes they are not. Trees do not drop their leaves in order to create these changes, but the changes come nonetheless, the final consequences of water moved from deep beneath the ground and sunlight captured and stored over the course of an entire summer.

A tree imports energy, water, and nutrients from a relatively small area around and beneath it to achieve ecological and evolutionary success through survival and reproduction. Weather conditions beyond its control force it to drop some of those hard-won imports, creating a whole set of unintended consequences for the tree itself as well as the surrounding ecosystem (Figure 1.1).

The central themes of this book reflect both the similarities and differences between cities and trees. Like a tree, urban areas change the habitats around them, and import and concentrate resources for a set of intended purposes. The concentration of these resources and the resulting outputs produce a panoply of unintended consequences. Compared with trees, however, urban areas draw a much wider array of resources from a much larger region, have a more pervasive effect on the environment they occupy, and export those effects over a broader area.

In this chapter, we lay out the groundwork for urban ecology. We begin by introducing the concept of the ecosystem engineer, a role played to perfection by urban humans. Next we meet some of the habitats in urban areas and the plants and animals that occupy them. This lays the foundation for reviewing the central questions of the science of ecology itself, how those questions fit within the urban context, and the major ways in which urban ecosystems differ from those with less human influence. Finally, we sketch the goals of the field of urban ecology, and of this book in particular.

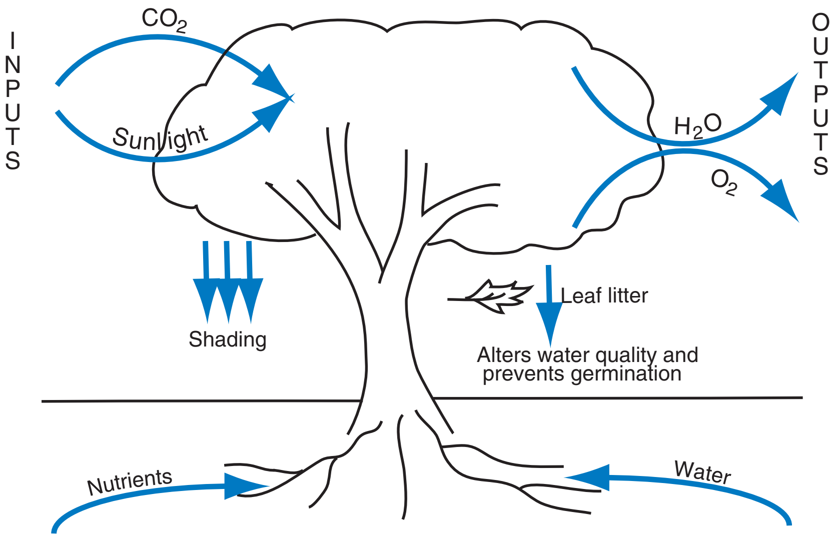

Figure 1.1 Like cities, trees import and export a whole range of materials, often transforming them in the process. These inputs and outputs create a wide array of intended and unintended consequences.

1.1 Engineered ecosystems

All organisms, however small, change their environment by their presence and by their use of resources. Most simply use available resources, with their existence affecting only a few nearby organisms. Early human hunter-gatherers may have shared the environment in this way, although early humans have been implicated in extinctions of some large mammals[18].

Other organisms, in contrast, have such major effects that they are termed *ecosystem engineers*[286] (Figure 1.2).

- Beavers build dams that change the flow of water, changing streams to ponds that flood surrounding forests.
- Woodpeckers drill holes in living or dead trees, making homes for themselves and other birds and animals, and opening up living trees to a range of pests and dead trees to decomposition.
- Trees change the climate and water flow patterns around themselves, and drop leaves that alter the properties of soil and determine which other plants can germinate and grow.
- Ants dig nests that alter the structure of soil and the movement of water within it, trim the vegetation around them, and import food and resources from many meters away. In this way, ants create “cities” with high densities of individuals that provide a revealing comparison with human cities.

Figure 1.2 Three ecosystem engineers: beavers, woodpeckers, and ants.

These animals and plants transform the environment, shifting the balance from one type of community, such as a forest with few aquatic plants, to another, such as a pond with few trees. Low intensity agriculture falls into this category, where only a relatively small proportion of land is used for crop production and the intervening tracts continue to support relatively undisturbed flora and fauna.

Ecosystem transformation can take place to various degrees. Changes can be subtle, such as a hole in a tree, or they can be extreme, such as an entire ecosystem being replaced. A coral reef can turn a large area of shallow open ocean into a richly diverse community. A non-native plant, such as cheatgrass *Bromus tectorum* that now dominates vast stretches of western North America, can replace native flora and fauna with a simplified and less diverse community. But it is modern humans who have mastered the art of ecosystem replacement.

Cities can change a shaded forest into a landscape of exposed rock, or a desert into a shaded forest. These transformed cities harbor an utterly different assemblage of plants and animals from the surrounding region, and have profoundly changed water movement and weather. The concentrated human demand for food requires large areas of high intensity agriculture, creating another set of novel environments that are dominated by single species such as corn, cattle, or soybeans.

Humans can be thought of as the definitive ecosystem engineers, making a whole range of changes simultaneously (damming rivers, building homes, moving resources, altering the climate) and over very large areas. But humans engineer the urban environment not just by modifying the locally available materials and resources, as beavers do by cutting and moving trees, but also by importing huge quantities of distant materials, energy, and nutrients, and exporting the resulting wastes. These unprecedented levels of input and output create, for the plants and animals that persist or flourish in the novel environment, an intensification of life similar to that experienced by the human residents of densely populated cities.

In some ways, however, humans have not so much created novel habitats as recreated or extended habitats favored by our distant ancestors[347]. During human evolution, people left the forests for savannas and sought refuges in cliffs, caves, and rocky outcrops. Early cities, built with natural stone, recreate many of the rocky aspects of these habitats, although new structures of glass and steel do not. The other component of the ancestral human habitat, the savanna of mixed open country and trees, has been mirrored in the mix of lawns, gardens, and trees that make up the suburbs that many people prefer to inhabit[419].

In urban areas, the effects of humans are never absent, almost by definition. Yet those effects vary in strength across the urban landscape, from preserved environments such as parks, transformed environments such as yards and gardens, to replaced environments such as buildings, roads, and landfills. How plants, animals, and other organisms make a living in this combination of environments is the central focus of this book.

1.2 Urban habitats

This book is about the functioning of ecosystems and the lives of plants and animals in the urban environment. But what, in fact, do we mean by “urban”? Many definitions are in use, often based on a specific population density threshold. For example, Japan defines urban areas by a density of at least 40 people per hectare. In comparison, the most densely populated city, Mumbai, India, has nearly 300 people per hectare, with the central zone packing over 1000 people into each hectare. This density exceeds that of a family of four living in a single-story 200 m^3 square meter house by a factor of five, even without accounting for the yard, street, or other spaces between homes. The most densely populated US state is New Jersey, with just under five people per hectare. If the

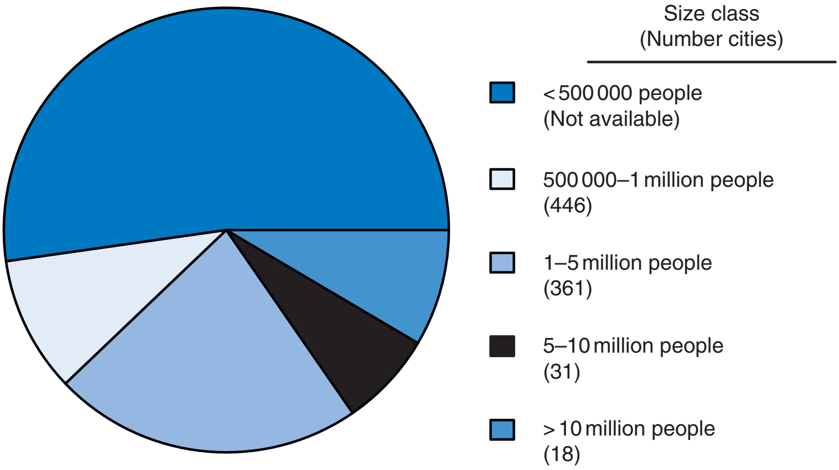

Figure 1.3 Percentage of urban people in cities of different sizes, along with the worldwide total number of such cities (after Gaston, 2010).

whole human population were spread evenly over the Earth's land area, there would be 0.5 people per hectare[612].

Other definitions involve the density of buildings or the distance between them[201]. This book is not tightly tied to any specific value, but focuses on how the changes characteristic of urbanization affect organismal and ecosystem processes. For planning purposes, different definitions can carry very distinct implications and must be considered more carefully[465].

By any definition, urban areas have grown vastly over the last three centuries. The first decade of the twenty-first century marks the first time in history when a majority of people live in cities, up from less than 10% in 1700[201]. This leads to a concentration of the human population, with more than half the population in a small fraction of the Earth's habitable area. In fact, cities take up only 1–3% of the Earth's area (depending on the definition and the method of analysis) with agriculture and grazing taking up roughly 20%[595].

There are now over 400 cities with more than 1 million people, up from a handful before 1800, such as ancient Rome, medieval Baghdad, or industrializing London. The current urban population is distributed among cities of widely different sizes, with the majority in smaller cities and relatively few in the megacities of over 10 million people (Figure 1.3).

All ecosystem engineers modify habitats, and the urban environment includes some of the most modified habitats on Earth, the *built environment*. The urban environment, however, consists of a wide variety of habitats from completely built up to those with few or no buildings or roads. Urban habitats vary in their degree of modification, the type and amount of inputs, including pollutants such as excess nutrients or poisons such as arsenic. Although traditionally thought of decreasing from more to less built as a function of distance from an urban core, urban land use is in fact a complex and

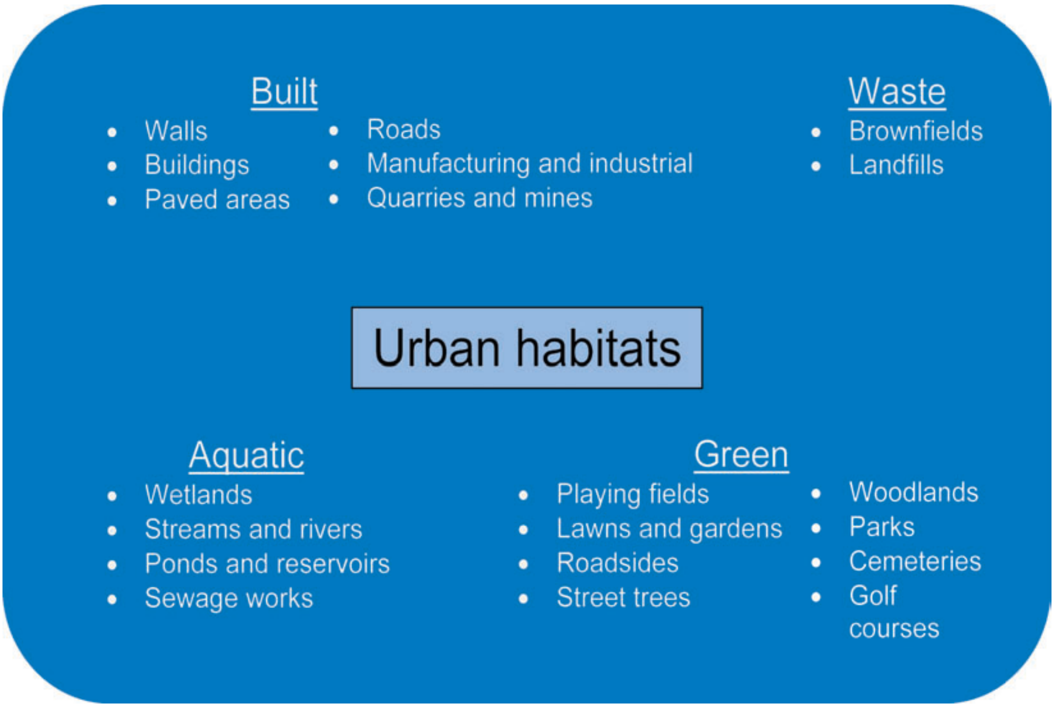

Figure 1.4 The various categories of urban habitat.

idiosyncratic response to historical and geological factors that rarely resembles a neat concentric arrangement[467].

We divide urban habitats into four broad categories (Figure 1.4).

1. **Built habitats** are structured primarily by human construction.
2. **Waste habitats** have been largely replaced with human discards.
3. **Green habitats** are covered primarily by plants.
4. **Aquatic habitats** are covered primarily by water.

Several careful inventories of urban lands show how different land uses are associated with different land types. In Manchester, UK, areas with high, medium, and low human population density differ in the percentage associated with different land cover[134] (Figure 1.5). The built environment is broken into buildings and other *impermeable surfaces*, surfaces that water cannot penetrate, like roads and parking lots. With rare exceptions, even the most heavily populated areas have a substantial proportion of land covered with vegetation, with much of that taking the form of managed grasslands or lawns[32] (Figure 1.6).

Although all ecosystems include a range of habitat types, urban areas are unusual in having profoundly different habitats in close proximity with sharp transitions (Figure 1.7). From the perspective of organisms that can survive only in a few of these

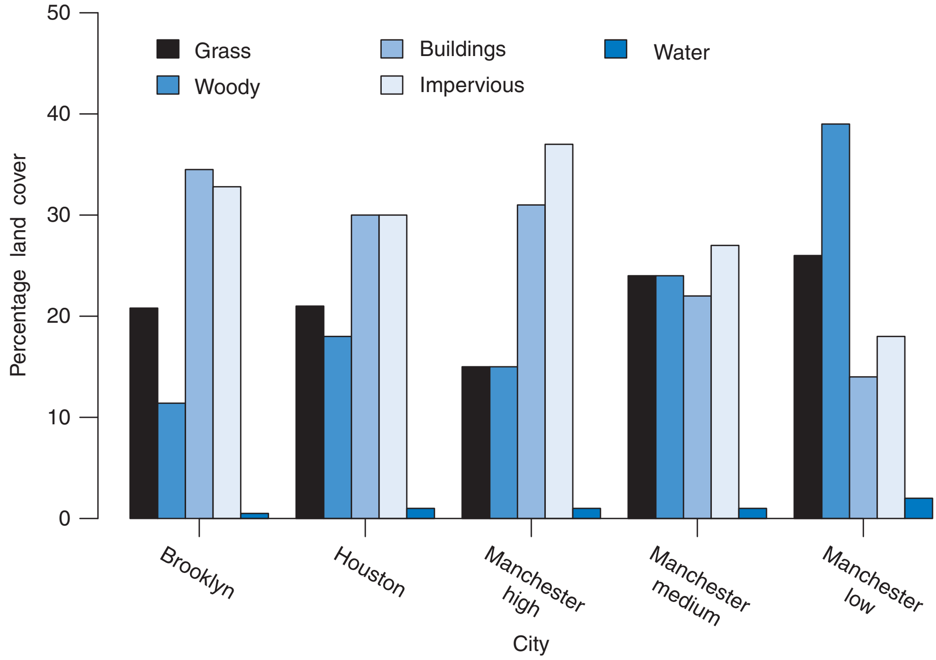

Figure 1.5 Distribution of habitats in two cities in the United States compared with in high, medium, and low density sections of Manchester, UK. High density areas have a preponderance of built habitats while low density areas are primarily green (after Douglas, 2011).

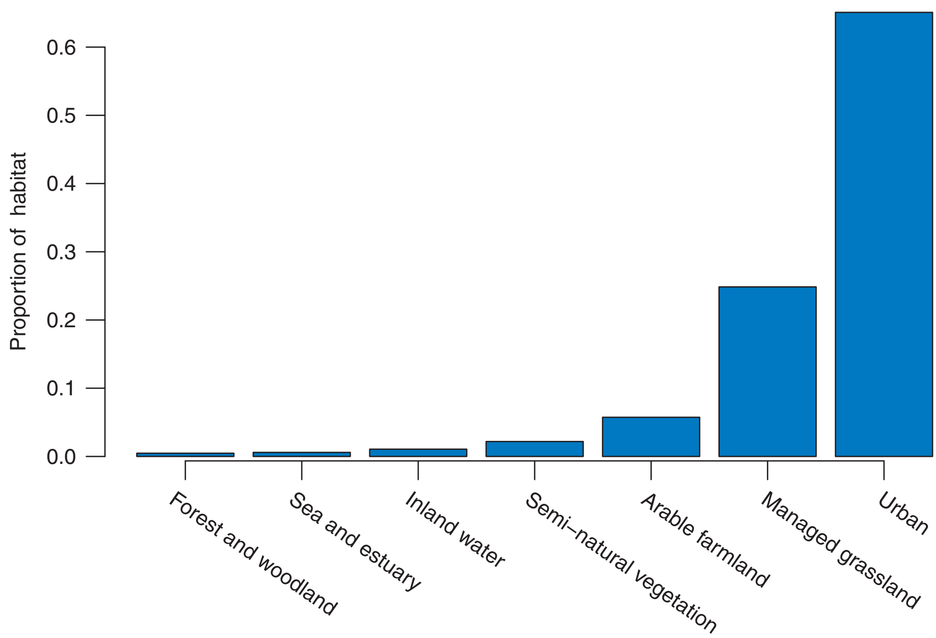

Figure 1.6 Distribution of habitats in London (after City Limits Report, 2002).

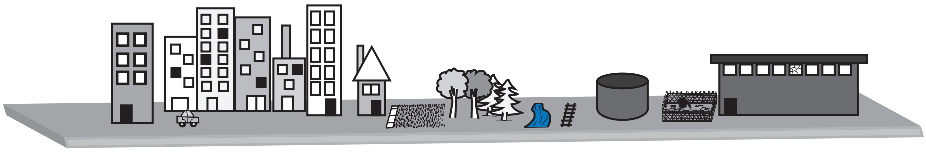

Figure 1.7 Urban areas contain a mix of contrasting and closely abutting habitats ranging from completely built by humans to nearly unmodified.

habitats, the urban environment can look like a set of habitat islands (often referred to as *patches*) separated by inhospitable environments.

Built habitats

Built habitats effectively define urban areas, designed for human use to the nearly complete exclusion of other organisms (Figure 1.8). Nonetheless, these habitats do support life, and the details of materials, architecture, and location determine which organisms can persist.

Walls in some cities cover as much vertical area as the city covers horizontally. Although generally quite inhospitable due to exposure to high levels of light, ultraviolet radiation, temperature and pollutants, and to low water availability, walls still accommodate some species. For example, walls built from porous materials such as limestone can support lichens, mosses, and climbing plants (Figure 1.9) along with a variety of algae and cyanobacteria[482]. Joints and cracks, particularly at the bottom of walls, provide places for water and nutrients to accumulate[607]. The plants that survive in these islands of life can support communities of small insects, spiders, and snails[576].

Buildings include more complex physical structures than just their walls. Window gardens and roof gardens support small communities of flowers and plants (Figure 1.10). The physical structures of buildings provide nesting sites for birds of prey such as falcons that feed on the pigeons and sparrows that inhabit the city center, roof-nesting birds such as gulls, shorebirds, and ravens, and bats and swifts that nest in chimneys and attics. Within buildings, humans share space with a variety of "pests", such as mice, rats, and roaches, in addition to overwintering insects like moths and beetles. Spiders capture insects that enter either accidentally or intentionally to find food, water, or trash.

Paved areas include sidewalks, parking lots, and city squares. Plants that colonize paved areas must overcome the challenges of trampling and compacted soil, but those that succeed can flourish in pavement gaps that accumulate water and nutrients. In the most trampled areas, only low-growing herbaceous plants and grasses tend

Figure 1.8 The built environment of Paris.

Figure 1.9 Aging building walls can provide habitat for hardy plants.

Figure 1.10 Window gardens, like these in Dublin, provide small patches of green on otherwise inhospitable walls.

to survive, and many of them are self-pollinating or wind-dispersed *annual plants* that live a fugitive existence in these short-lived patches. Other areas, particularly close to the bases of walls, are trampled less often, and longer-lived and taller plants can survive.

Roads are distinguished from other paved areas by vehicle traffic. Roads themselves tend to support few if any plants and animals as residents, and can reduce habitat quality for many hundreds of meters through modification of neighboring habitat, noise, and other pollution[145]. Animals that attempt to cross roads may perish in the attempt, and roads thus act as barriers to *dispersal*. Underpasses, sometimes designed specifically for animal passage, and drainage culverts under highways are used by many species (including humans) as a relatively safe way to cross roads.

Waste habitats

The effects of urban economic and business activity spread beyond the residences and workplaces where human activity is concentrated. When buildings or parking lots are abandoned, they remain in the landscape as *brownfields*. Discarded materials are transported and concentrated in landfills.

Brownfields are manufacturing and industrial areas that have been abandoned or are rarely used (Figure 1.11). As in other highly disturbed sites, the first species to arrive are typically wind-dispersed annual plants and hardy grasses, followed by taller perennial plants and, in sufficiently wet climates, by trees. Sites with large quantities of rubble or trash can have poor water retention and soils that are inhospitable to many plants.