13
Cities: Managing Densely Settled Social–Ecological Systems

J. Morgan Grove

Introduction

Why are Cities and Urbanization Important?

The transition from a rural to urban population represents a demographic, economic, cultural, and environmental tipping point. In 1800, about 3% of the world's human population lived in urban areas. By 1900, this proportion rose to approximately 14% and now exceeds 50% in 2008. Nearly every week 1.3 million additional people arrive in the world's cities (about 70 million a year), with increases due to migration being largest in developing countries (Brand 2006, Chan 2007). People in developing countries have relocated from the countryside to towns and cities of every size during the past 50 years. The urban population on a global basis is projected by the UN to climb to 61% by 2030 and eventually reach a dynamic equilibrium of approximately 80% urban to 20% rural dwellers that will persist for the foreseeable future (Brand 2006, Johnson 2006). This change from 3% urban population to the projected 80% urban is a massive change in the social–ecological dynamics of the planet.

The spatial extent of urban areas is growing as well. In industrialized nations the conversion of land from wild and agricultural uses to urban and suburban settlement is growing at a faster rate than the growth in urban population. Cities are no longer compact (Pickett et al. 2001); they sprawl in fractal or spider-like configurations (Makse et al. 1995) and increasingly intermingle with wildlands. Even for many rapidly growing metropolitan areas, suburban zones are growing faster than other zones (Katz and Bradley 1999). The resulting new forms of urban development include edge cities (Garreau 1991) and a wildland–urban interface in which housing is interspersed in forests, shrublands, and desert habitats.

Accompanying this spatial change is a change in perspectives and constituencies. Although these habitats were formerly dominated by agriculturists, foresters, and conservationists, they are now increasingly dominated by people possessing resources from urban systems, drawing upon urban experiences, and expressing urban habits.

J.M. Grove (✉)
Northern Research Station, USDA Forest Service,
Burlington, VT 05403, USA
e-mail: mgrove@fs.fed.us

F.S. Chapin et al. (eds.), *Principles of Ecosystem Stewardship*,

DOI 10.1007/978-0-387-73033-2_13,

An important consequence of these trends in urban growth is that cities have become *the* dominant global human habitat of this century in terms of geography, experience, constituency, and influence. This reality has important consequences for social and ecological systems at global, regional, and local scales, as well as for natural resource organizations attempting to integrate ecological function with human desires, behaviors, and quality of life.

Urbanization is a Dynamic, Social, and Ecological Phenomenon

Urbanization is having significant and unpredicted effects on the human global population. According to UN projections, the world's overall fertility rate will decline below replacement levels by 2045, due in large part to declining fertility in cities. In cities women tend to have both more economic opportunities and more reproductive control, and the economic benefit of children depends less on the quantity of children than on their quality, particularly in terms of education. This trend is amplified by the fact that the social and financial costs of childbearing and childrearing continue to rise in cities (Brand 2006).

Birthrates on a national basis have already dropped as a result of rapid urbanization in both developed and developing nations. In the case of the developing world, the fertility rate has declined from six children per woman in 1970 to 2.9 currently. In twenty emerging-economy countries—including China, Chile, Thailand, and Iran—the fertility rate has declined below the replacement rate of 2.1 children per woman (Brand 2006).

What this means in a global, long-term demographic context is that, although the world's population doubled in a single generation for the first time in human history, from 3.3 billion in 1962 to 6.5 billion now, this is unlikely to occur again. The "population momentum" of our current global population and our children will carry the world population to a peak of 7.5–9 billion around 2050 and then decline (Brand 2006).

Urbanization creates both ecological vulnerabilities and efficiencies. For instance, coastal areas, where many of the world's largest cities occur, are home to a wealth of natural resources and are rich with diverse species, habitat types, and productive potential. They are also vulnerable to land conversion, changes in hydrologic flows, outflows of waste, and sea level rise (see Chapter 12; Grimm et al. 2008). In the USA, 10 of the 15 most populous cities are located in coastal counties (NOAA 2004) and 23 of the 25 most densely populated US counties are in coastal areas. These areas have already experienced ecological disruptions (Couzin 2008).

The link between urbanization and coastal areas is evident on a global basis as well. Because of the coastal locations of many major cities, urban migration also brings people to coastlines around the world in one of the greatest human migrations of modern times. The most dramatic population growth has occurred in giant coastal cities, particularly those in Asia and Africa. Many experts expect that cities will have to cope with almost all of the population growth to come in the next two decades, and much of this increase will occur in coastal urban centers (Brand 2006, Johnson 2006).

While ecological vulnerabilities are significantly associated with urban areas, urbanization also fosters ecological efficiencies. The ecological footprint of a city, i.e., the land area required to support it, is quite large (Folke et al. 1997, Johnson 2006, Grimm et al. 2008). Cities consume enormous amounts of natural resources, while the assimilation of their wastes—from sewage to the gases that cause global warming—also are distributed over large areas. For example, London occupies 170,000 ha and has an ecological footprint of 21 million hectares—125 times its size (Toepfer 2005). In Baltic cities, the area needed from forest, agriculture, and marine ecosystems corresponds to approximately 200 times the area of the cities themselves (Folke et al. 1997).

Ecological footprint analysis can be misleading, however, for numerous reasons (Deutsch et al. 2000). It ignores the more important question of efficiency, defined here as persons-to-area: how much land area (occupied area and footprint area) is needed to support a certain number of persons? From this perspective, it becomes clear that urbanization is critical to delivering a more ecologically sustainable and resource-efficient world because the per-person environmental impact of city dwellers is generally lower than people in the countryside, and it can be reduced still further (Brand 2006, Johnson 2006, Grimm et al. 2008). For instance, the average New York City resident generates about 29% of the carbon dioxide emissions of the average American. By attracting 900,000 more residents to New York City by 2030, New York City can actually save 15.6 million metric tons of carbon dioxide a year relative to the emissions of a more dispersed population (Chan 2007).

The combined effects of urbanization on migration, fertility, and ecological efficiency may mean that social–ecological pressures on natural systems can be dramatically reduced in terms of resources used, wastes produced, and land occupied. This may mean that cities can provide essential solutions to the long-term social–ecological viability of the planet given current population trends for this century.

Are Urban Areas Ecosystems?

Earlier chapters about low-density, social–ecological systems such as drylands, forests, and oceans took pains to point out the pervasive importance of social processes in governing social–ecological dynamics. Conversely, the fundamental importance of *ecological* processes is sometimes overlooked in cities. An **ecosystem** is an assemblage of organisms interacting with the physical environment within a specified area (see Chapter 1; Tansley 1935, Bormann and Likens 1979). When Tansley (1935) originated the term ecosystem, he carefully noted that "*... ecology must be applied to conditions brought about by human activity. The 'natural' entities and the anthropogenic derivatives alike must be analyzed in terms of the most appropriate concepts we can find*." Since the 1950s, social scientists have contributed to an expanded view of ecosystems inclusive of humans along a continuum from wilderness to urban areas (Hawley 1950, Schnore 1958, Duncan 1961, 1964, Burch and DeLuca 1984, Machlis et al. 1997). Public health researchers and practitioners have provided supplemental perspectives (Northridge et al. 2003), and transdisciplinary approaches have been proposed to implement a social–ecological framework (Chapters in this book; Elmqvist et al. 2004, Collins et al. 2007).

An urban ecosystem perspective retains a concern with ecological structure and function, including biophysical fluxes (Stearns and Montag 1974, Boyden et al. 1981, Burch and DeLuca 1984a, Warren-Rhodes and Koenig 2001) and ecological regulation of system dynamics (Groffman et al. 2003, Pickett et al. 2008). At the same time, demographic, social, and economic structures and fluxes clearly exert important controls over these dynamics as well (Burch and DeLuca 1984a, Grove and Burch 1997, Machlis et al. 1997). Integrating social–ecological structure, function, and regulation of urban ecosystems is therefore essential to an understanding of the ecology of cities (Grimm et al. 2000, Pickett et al. 2001) as open complex adaptive systems that can be characterized in terms of vulnerability and resilience. In contrast to rural areas, urban social–ecological systems are distinguished by a high population density, the built environment, and livelihoods that do not directly depend on the harvest or extraction of natural resources. Finally, ecosystem service concerns are likely to differ between cities and many rural areas, particularly cultural services such as social identity, knowledge, spirituality, recreation, and aesthetics.

Why Use the Approaches Described in This Book?

In very broad historical terms we have begun a new paradigm for cities. Since the 1880s, a great deal of focus has centered on the "Sanitary City," with concern for policies, plans, and practices that promoted public health (Melosi 2000). While retaining the fundamental concern for the Sanitary City, we have begun to envelope the Sanitary City paradigm with a concern for the "Sustainable City," which places urbanization in a social–ecological context on a local, regional, and global basis.

Urban ecology has a significant role to play in this context. Already, urban ecology has an important applied dimension as an approach used in urban planning, especially in Europe. Carried out in city and regional agencies, the approach combines ecological information with planning methodologies (Hough 1984, Spirn 1984, Schaaf et al. 1995, Thompson and Steiner 1997, Pickett et al. 2004, Pickett and Cadenasso 2007).

Cities face challenges that are increasingly complex and uncertain. Many of these complexities are associated with changes in climate, demographics, economy, and energy at multiple scales. Because of these complex, interrelated changes, concepts such as resilience, vulnerability, and ecosystem services may be particularly useful for addressing current issues and opportunities as well as preparing for potential future scenarios requiring long-term, and frequently capital-intensive, change.

Cities have already begun to address these challenges and opportunities in terms of policies, plans, and management. For example, on June 5, 2005, mayors from around the globe took the historic step of signing the Urban Environmental Accords—Green City Declaration with the intent of building ecologically sustainable, economically dynamic, and socially equitable futures for its urban citizens. The Accord covered seven environmental categories to enable sustainable urban living and improve the quality of life for urban dwellers: (1) energy, (2) waste reduction, (3) urban design, (4) urban nature, (5) transportation, (6) environmental health, and (7) water (www.urbanaccords.org). International associations such as *ICLEI-Local Governments for Sustainability* (http://www.iclei.org/) are developing and sharing resources to address these issues.

The ability to address these seven categories will require numerous, interrelated strategies. New York City's plaNYC for *A Greener, Greater New York* (http://www.nyc.gov/html/planyc2030/downloads/pdf/full_report.pdf), for example, includes 127 different but interrelated strategies for making the city more sustainable, dynamic, and equitable. However, many cities are managed in disciplinary and fragmented ways. In some sense, city agencies and non-governmental organizations (NGOs) too often resemble traditional university departments separated by academic disciplines. The essence of this situation readily maps to Yaffee's (1997) "recurring nightmares" (Chapter 4): (1) a process in which short-term interests out-compete long-term visions and concerns; (2) conditions in which competition supplants cooperation because of the conflicts that emerge in management issues: (3) the fragmentation of interest and values; (4) the fragmentation of responsibilities and authorities (sometimes called "functional silos" or "stove pipes"); and (5) the fragmentation of information and knowledge, which leads to inferior solutions.

To address these "recurring nightmares," universities and cities alike have begun to reorganize themselves in part by creating Offices of Sustainability (Deutsch 2007). A fundamental challenge to these types of offices and the polycentric networks in which they exist will be to understand urban ecosystems as complex adaptive systems in order to build resilient urban futures that are ecologically sustainable, economically dynamic, and socially equitable.

The following section applies several of the resilience principles described earlier in this book for understanding and building more resilient urban futures: (1) cities are open, and multiscale systems, (2) cities are heterogeneous and ecosystem composites, and (3) cities are complex adaptive systems.

Principles

Cities are Open, and Multiscale Systems

The recognition that cities are open multiscale systems has only recently become evident in the ecological study of urban areas (Pickett et al. 1997a, Grimm et al. 2000). Urban ecology began as the study of "ecology *in* cities," which focused historically on ecologically familiar places and compared urban and nonurban areas: parks as analogs of rural forests (e.g. Attorre et al. 1997, Kent et al. 1999) and vacant lots as analogs of fields or prairies (Vincent and Bergeron 1985, Cilliers and Bredenkamp 1999). Urban streams, rock outcrops, and remnant wetlands were the object of ecological studies similar in scope and method to those conducted in nonurban landscapes. There is a long European tradition of these types of ecological studies *in* cities (Sukopp et al. 1990, Berkowitz et al. 2003).

The study of "ecology *of* cities" builds upon the focused efforts of "ecology *in* cities," while incorporating a more expansive approach to cities that is consistent with the social–ecological approaches described in this book (see Chapters 1–5). In particular, the ecology-*of*-cities approach developed in response to the recognition of the open and multiscale nature of cities. Input–output budgets of a city were the first type of ecology-*of*-cities approach addressing the open nature of cities. This budgetary approach relies on a "closed box" approach to ecosystems. Inputs and outputs are measured and the processes within the system are implicitly assumed to be homogeneous. This approach is similar to the ecosystem ecology of the 1960s and 1970s and has been used by ecologists (Bormann and Likens 1967), environmental historians (Cronon 1991), and social scientists (Stearns and Montag 1974). The material and energy budget of Hong Kong (Boyden et al. 1981) and the nitrogen budget of New Haven, Connecticut (Burch and DeLuca 1984) are examples. The lack of interdisciplinary experts noted by Boyden et al. (1981) and the apparent lack of interest by mainstream ecology constrained this approach to cities. However, the two urban projects of the Long-Term Ecological Research (LTER) Network, the Baltimore Ecosystem Study (BES) and Central Arizona Phoenix (CAP) program, have developed nitrogen budgets in terms of both internal dynamics and inputs–outputs for their urban ecosystems (Baker et al. 2001, Groffman et al. 2004).

Ecology *of* cities in its contemporary form incorporates new approaches from ecology in general and from ecosystem ecology in particular. It also benefits from relatively new specialties such as landscape ecology, which focuses on the functional consequences of spatial heterogeneity. It further benefits from increasing interdisciplinary work and training. Together, these developments make the inclusive approach to ecology *of* cities very different from the examples from the 1970s and early 1980s. There are several reasons for this difference. First, the ecology *of* cities addresses the whole range of habitats in metropolitan systems, not just the green spaces that are the focus of ecology *in* cities. Second, spatial heterogeneity, expressed as gradients or mosaics, is critical for explaining interactions and changes in the city. Third, the role of humans at multiple scales of social organization, from individuals through households and ephemeral associations, to complex and persistent agencies, is linked to the biophysical scales of the metropolis. Finally, humans and their institutions are a part of the ecosystem, not simply external, negative influences. This opens the way toward understanding feedbacks among the biophysical and human components of the system, toward placing them in their spatial and temporal contexts, and toward examining their effects on ecosystem inputs and outputs at various social scales, including individuals, households, neighborhoods, municipalities, and regions (Grove and Burch 1997).

Cities are Heterogeneous and Ecosystem Composites

Urban ecosystems are notoriously heterogeneous or patchy (Jacobs 1961, Clay 1973). Biophysical patches are a conspicuous layer of heterogeneity in cities. The basic topography, although sometimes highly modified, continues to govern important processes in the city (Spirn 1984). The watershed approach to urban areas has highlighted the importance of slopes, and of patchiness along slopes, in water flow and quality (Band et al. 2006). Steep areas are often the sites of remnant or successional forest and grassland in and around cities. Soil and drainage differ with the underlying topography. Vegetation, both volunteer and planted, is an important aspect of biophysical patchiness. The contrast in microclimate between leafy, green neighborhoods versus those lacking a tree canopy is a striking example of biotic heterogeneity (Nowak 1994). Additional functions that may be influenced by such patchiness include carbon storage (Jenkins and Riemann 2003), animal biodiversity (Adams 1994, Hostetler 1999, Niemela 1999), social cohesion (Grove 1995, Colding et al. 2006), and crime (Dow 2000, Troy and Grove 2008).

Social and economic heterogeneity is also pronounced in and around cities. Patchiness can exist in such social phenomena as economic activity and livelihoods, family structure and size, age distribution of the human population, wealth, educational level, social status, and lifestyle preferences (Burch and DeLuca 1984, Field et al. 2003).

Temporal dynamics are just as important as spatial pattern, since none of these social patterns are fixed in time. This insight is a key feature of the socio-spatial (Gottdiener and Hutchinson 2001) and patch dynamics approaches to urban ecosystems (Pickett et al. 1997b, Grimm et al. 2000, Pickett et al. 2001). It is a critical feature for including the built nature of cities as well. Most people, and indeed most architects and designers, assume that the built environment is a permanent fixture. However, buildings and infrastructure change, as do their built and biophysical context. This elasticity in the urban system suggests a powerful way to reconceptualize urban design as an adaptive, contextualized pursuit (Pickett et al. 2004, Shane 2005, Colding 2007, McGrath et al. 2008). Such dynamism combines with the growing recognition of the role of urban design in improving the ecological efficiencies and processes in cities. Although this application of patch dynamics is quite new, it has great promise to promote the interdisciplinary melding of ecology and design and to generate novel designs with enhanced environmental benefit (McGrath et al. 2008). Thus, patches in urban systems can be characterized by biophysical structures, social structures, built structures, or a combination of the three at multiple scales (Cadenasso et al. 2006).

Not only are urban areas heterogeneous, they are ecological composites, constituted by many of the ecosystem types described in this book: forests, drylands, freshwaters, estuaries, coastal areas, and urban gardens (see Chapters 8–12), combined with the social attributes described in Chapters 3–4. Because cities are ecological composites, they often include the ecological and social characteristics associated with these individual ecosystem types. In the case of freshwaters, for example, cities bordering lakes and rivers are affected by the spatial heterogeneity of flows; the interaction of fast and slow variables; nonlinearities and thresholds in system change; the need to account for blue and green water; and management systems that are fragmented and require continuous adaptation. Likewise, in the case of estuaries, social sources of resilience depend upon monitoring programs, spatial complexity, some degree of localized management control, and a willingness to entertain and implement actively adaptive, experimental management policies (Felson and Pickett 2005). Because of this urban ecological composition, there is a great deal to learn and adapt from the experiences and knowledge of these particular ecosystem types to urban settings.

Cities are Complex Adaptive Systems

The fact that cities are complex adaptive systems is manifest in the definition provided in Chapter 1: *Systems whose components interact in ways that cause the system to adjust or "adapt" in response to changes in conditions. This is a simple consequence of interactions and feedbacks*. These interactions and feedbacks are expressed in urban areas in several ways.

Cities, like all social–ecological systems, exist in a state of nonequilibrium (Pickett and Cadenasso 2008) as a result of both major disruptions (pulses) and chronic stresses (presses). Pulses include disease epidemics, droughts, famines, floods, earthquakes, fires, and warfare. Long-term presses result from demographic changes caused by immigration, emigration, and/or aging; changes in economy through transitions from agriculture, manufacturing, shipping, and service economies (Fig. 13.1); and changes in transportation systems including water, rail, auto, and air. The dynamic results of these long-term press and pulse forces are manifest in Batty's (2006) long-term rank clocks for urban areas in the USA (1790–2000) and the planet (430 BC–AD 2000), which illustrate the

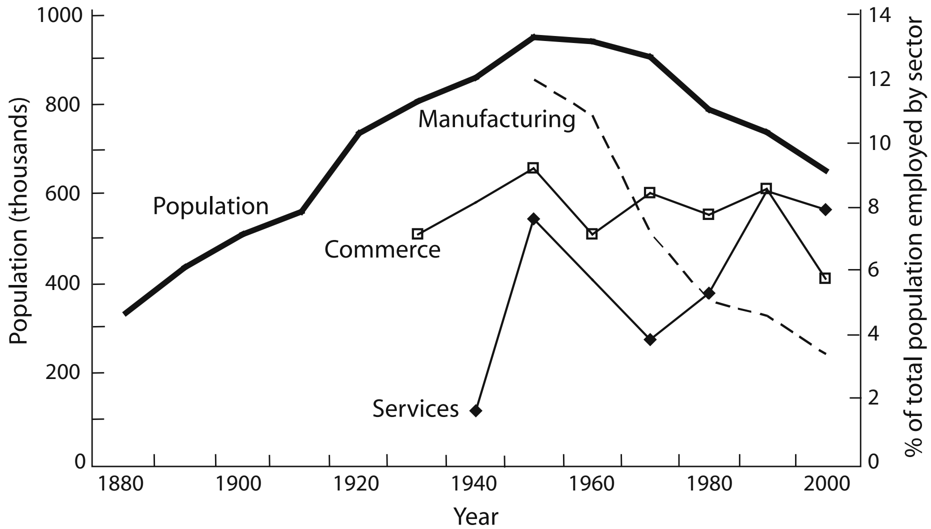

FIGURE 13.1. Long-term trends in population and economy for the city of Baltimore, USA, 1880–2000. Data from the LTER Ecotrends Project: Socioeconomic Catalogue (http://coweeta.ecology.uga.edu/trends/catalog˙trends˙base2.php).

long-term dynamics of cities in terms of population size over time (Figs. 13.2, 13.3).

Social institutions (the rules of the game) play a key role in the adjustments or adaptations of cities to changing conditions (see Chapter 4, Burch and DeLuca 1984, Machlis et al. 1997). Institutions, such as property rights, direct the allocation of resources to individuals

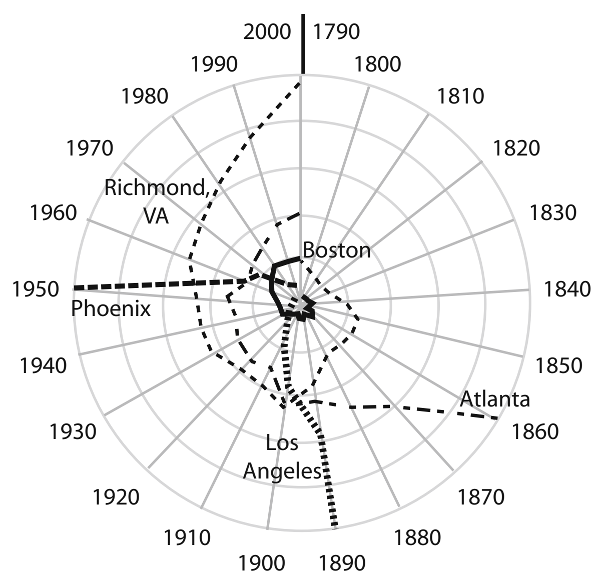

FIGURE 13.2. The trajectory of relative population rank of four of the 100 most populous US cities from 1790 to 2000. The most populous city is at the center of the rank clock, and the hundredth city is at the periphery. Boston, an important colonial city in the northeastern USA, has always been one of the largest US cities. Richmond, another important colonial city, declined in importance during the early twentieth century, as new cities like Los Angeles in the western USA became important. Phoenix, a desert city attractive to retired persons, became important only in the last 50 years. Very few cities have remained among the most populous US cities throughout their history. Modified from Batty (2006).

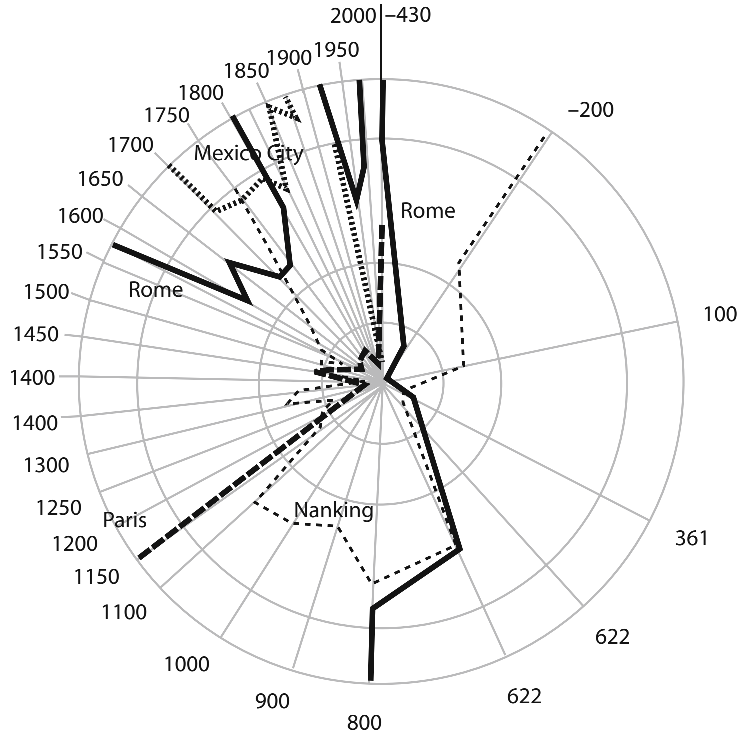

FIGURE 13.3. The trajectory of relative population rank of 4 of the 50 most populous world cities from 430 BC to 2000 AD. The most populous city is at the center of the rank clock, and the fiftieth city is at the periphery. Rome (Italy) and Nanking (China) remained important throughout most of this 2500-year history. Most cities, however, have had a highly volatile population history, with many cities of the developed world (e.g., Paris, France) declining in relative rank during the industrial revolution and cities from the developing world (e.g., Mexico City) becoming more populous, a trend that is likely to continue in the future. Modified from Batty (2006).

and organizations and affect human interactions. Social institutions can be thought of as dynamic solutions to universal needs, including health, justice, faith, commerce, education, leisure, government, and sustenance (Machlis et al. 1997). While the structure of these institutions is important, structure should not be mistaken for function: the health of individuals and populations, the exchange of goods and services, the provisioning of food, water, energy, and shelter (Machlis et al. 1997). In this context, different forms of social institutions might yield identical functions. The ability of social institutions to change in form and yet continue to yield comparable institutional functions is a key element to the adaptive capacity of urban social–ecological systems.

Social institutions are interrelated and often depend upon polycentric governance and social capital within and among cities (see Chapters 4 and 5). For instance, social capital is a crucial factor differentiating "slums of hope" from "slums of despair" (Box 13.1; Brand 2006). This is where community-based organizations (CBOs) and NGOs that support local empowerment play critical roles (Colding et al. 2006, Lee and Webster 2006, Andersson et al. 2007). Typical CBOs include, according to a 2003 UN report, "community theater and leisure groups; sports groups; residents associations or societies; savings and credit groups; child care groups; minority support groups; clubs; advocacy groups; and more. . . . CBOs as interest associations have filled an institutional vacuum, providing basic services such as communal kitchens, milk for children, income-earning schemes and cooperatives" (Brand 2006). CBOs and NGOs can be diverse, not necessarily focused on "environmental" issues,

Box 13.1. Slums: Past and Present

It can be argued that cities have rarely been the result of grand master plans and that all of the world's current major cities began as disreputable shantytowns (Brand 2006, Neuwirth 2006). Slums remain a prominent issue of concern today and, in many ways, the megacities of the developing world are struggling with the same issues of uncharted and potentially unsustainable growth that industrial cities in Europe and the USA faced in the late 1800s and early 1900s (Johnson 2006). By 2015 for instance, the five largest cities on the planet will be Tokyo, Mumbai, Dhaka, Sao Paulo, and New Delhi, with populations greater than 20 million each. Most of this growth will occur in shantytowns: built on illegally occupied land without the guidance of civic planning professionals or traditional infrastructure to support its growth. By some estimates, 25% of the world's population will live in shantytowns by 2030 (Johnson 2006).

Although shantytowns lack the formal plans and infrastructure of urban areas in developed countries, they are dynamic places of social innovation and creativity with economic activities of ordinary life: shops, banks, and restaurants. All of this has been accomplished without urban planners, without government-created infrastructure, and without formal property deeds. While these shantytowns might offend some persons' sense of order, these shantytowns are not exclusively places of poverty and crime. In fact, they are where the developing world goes to get out of poverty (Brand 2006). They are a reminder that different social forms might yield identical functions; that the ability of social institutions to change in form yet continues to yield comparable institutional functions is a key element to the adaptive capacity of urban social–ecological systems.

It might be negligent to claim shantytown residents do not need nor want formal civic resources in terms of expertise, investments, and opportunities in areas such as epidemiology, public infrastructure, education, engineering, waste management, and recycling (Brand 2006, Johnson 2006). But it would also be negligent to not recognize the enormous variety of shantytown experiences among the thousands of "emerging cities with different cultures, nations, metropolitan areas, and neighborhoods. From this variety is emerging an understanding of best and worst governmental practices—best, for example, in Turkey, which offers a standard method for new squatter cities to form; worst, for example, in Kenya, which actively prevents squatters from improving their homes. Every country provides a different example. Consider the extraordinary accomplishment of China, which has admitted 300 million people to its cities in the last 50 years without shantytowns forming, and expects another 300 million to come" (Brand 2006:13). And in this process it might be important to examine the ecological footprint of shantytowns, with their extreme density, low-energy use, and ingenious practices of recycling everything. Maybe there are ideas there that could be generalized on a global basis (Brand 2006).

Religious groups play significant roles as well. According to Davis (2006) "Populist Islam and Pentecostal Christianity (and in Bombay, the cult of Shivaji) occupy a social space analogous to that of early twentieth-century socialism and anarchism. In Morocco, for instance, where half a million rural emigrants are absorbed into the teeming cities every year, and where half the population is under 25, Islamicist movements like 'Justice and Welfare,' founded by Sheik Abdessalam Yassin, have become the real governments of the slums: organizing night schools, providing legal aid to victims of state abuse, buying medicine for the sick, subsidizing pilgrimages and paying for funerals." He adds that "Pentecostalism is. . .the first major world religion to have grown up almost entirely in the soil of the modern urban slum" and "since 1970, and largely because of its appeal to slum women and its reputation for being colour-blind, [Pentecostalism] has been growing into what is arguably the largest self-organized movement of urban poor people on the planet" (Brand 2006, Johnson 2006).

The networks among cities are important too. As New York City prepared its *Greener, Greater New York* plan, David Doctoroff, deputy mayor for Economic Development, noted that, "We shamelessly stole congestion pricing from London and Singapore, renewable energy from Berlin, new transit policies from Hong Kong, pedestrianization and cycling from Copenhagen, bus rapid transit from Bogota, and water-cleaning mollusks from Stockholm" (Chan 2007).

Many of the social and ecological interactions and feedbacks in urban ecosystems confer resilience: the capacity of a social–ecological system to absorb a spectrum of shocks or perturbations without fundamentally altering its structure, functioning, and feedbacks. Resilience depends on (1) adaptive capacity; (2) biophysical and social legacies that contribute to diversity and provide proven pathways for rebuilding; (3) the capacity of people to plan for the long term within the context of uncertainty and change; (4) a balance between stabilizing feedbacks that buffer the system against stresses and disturbance and innovation that creates opportunities for change; and (5) the capacity to adjust governance structures to meet changing needs (see Chapter 1; Gunderson and Holling 2002, Folke 2006, Walker and Salt 2006).

Biophysical and social legacies can significantly affect the resilience of urban systems. These legacies or dependencies can be temporal or spatial. For instance, historic residential segregation and industrial development in Baltimore, Maryland, created a situation in which predominantly white neighborhoods are in proximity to TRI sites (toxic release inventory sites; Boone 2002). Legacies [dependencies] can be spatial too. For example, as police departments decide how to allocate scarce resources, part of their decision-making process is to label neighborhoods as green (no crime problems), yellow (some crime problems), and red (severe crime problems). Whether the police department expends resources in a neighborhood depends upon their assessment of that neighborhood as well as adjacent neighborhoods. Thus, if a neighborhood is coded yellow and is bordering green neighborhoods, police resources are dedicated to the yellow neighborhood to reduce the risk of spillover or contagion into green neighborhoods. If a neighborhood is coded yellow and is bordering red neighborhoods, police resources may not be invested because the likelihood of decline from yellow to red is too great. Finally, temporal and spatial legacies can be **prospective**. In other words, people take specific actions in specific places today because they believe those actions will influence the capacity of future residents and governance networks to meet short-term and long-term challenges and opportunities.

Working prospectively to create social-ecological legacies is a profound challenge. As Doctoroff notes (Chan 2007), "sustainability is an almost sacred obligation to leave this city better off for future generations than we who are here today have found it." The greatest challenges are not matters of technology, but rather issues of "will and leadership." Short-term sacrifices for long-term gains "are not things that, by its very nature, the political system is equipped to decide."

While Doctoroff's observation is well-founded, there is already evidence for urban resilience. Cities are the most long-lived of all human organizations. The oldest surviving corporations, the Sumitomo Group in Japan, and Stora Enso in Sweden, are about 400 and 700 years old, respectively. The oldest universities in Bologna and Paris have been in place more than a 1,000 years. The oldest living religions, Hinduism and Judaism, have existed more than 3,500 years. In contrast to these corporations and religions, the town of Jericho has been continuously occupied for 10,500 years and its neighbor, Jerusalem, has been an important city for 5,000 years, though it has been conquered or destroyed 36 times and experienced 11 religious conversions (Brand 2006). Many cities die or decline to irrelevance, but some thrive for millennia (Batty 2006, Brand 2006, Johnson 2006; Fig. 13.3).

Part of a city's durability is associated with the fact that it is constantly changing. In Europe, cities replace 2–3% per year of their material fabric (buildings, roads, and other construction) by demolishing and rebuilding it. In the USA and the developing world, that turnover occurs even faster. Yet within all of that turnover something about a city remains deeply constant and self-inspiring (Brand 2006). Some combination of geography, economics, and cultural identity ensures that even a city destroyed by war (Warsaw, Dresden, Tokyo) or fire (London, San Francisco) will often be rebuilt (Johnson 2001, Brand 2006, Johnson 2006). Thus, the resilience of urban ecosystems rarely depends upon a single factor, but a diversity of interacting social–ecological feedbacks.

Cities as Functional Social–Ecological Systems

Ecosystem Services and the Dynamics of Cities

The existence, significance, and dynamics of ecosystem services—supporting, provisioning, regulating, and cultural services—have been only partially characterized in urban areas (Bolund and Hunhammar 1999, Colding et al. 2006, Farber et al. 2006, Andersson et al. 2007). Their existence in urban areas is increasingly well-documented, although frequently not identified as ecosystem services per se. For instance, there is growing knowledge and data about urban ecosystems describing soil dynamics and nutrient flux regulation (supporting); production of freshwater, food, and biodiversity (provisioning); modification of climate, hydrology, and pollination (regulation); and links to social identity and spirituality and importance to recreation and aesthetics (cultural).

The significance of these ecosystem services is often poorly understood. One approach is to estimate the monetary value of ecosystem services, for example, the capacity of ecosystems to purify water for New York City (see Chapter 9). Although this approach is valuable in addressing certain issues, it may miss important aspects of the dynamics of urban ecosystems: "Do variations in ecosystem services affect the desirability of cities?" In other words, do ecosystem services affect where households (families) and firms (businesses) choose to locate in order to avoid some places (push) and seek other places (pull)? Clearly, this may be the case as households and firms seek places that afford, for instance, clean air and water, recreation and communal opportunities, and efficiencies in energy and transportation. In contrast to other types of ecosystems, provision of and access to these ecosystem services is regulated by a combination of ecological, social, and built systems.

The dynamics or interactions among ecosystem services in urban areas are poorly understood. Preferences for ecosystem services may vary over time. For instance, in the early 1900s in Baltimore, Maryland, households preferred to live close to industrial factories where they worked and were not concerned with air quality. With growing knowledge about the relation between air quality and health, households now value clean air more than proximity to their work place, and desirability of these neighborhoods has declined (Boone 2002).

Preferences for ecosystem services may vary among social groups. Certain ethnic groups may prefer different recreation or communal opportunities. Demographics or life-stage is important too. Young families with children may prefer houses with large yards and nearby play-parks for their children, while retired couples may prefer to live in apartments close to greenways and waterfront promenades for their daily walks.

Preferences for ecosystem services may be conditioned by interacting factors. For instance, living close to a park in Baltimore is generally highly desirable. Proximity to a park increases the value of a home in neighborhoods with low levels of crime. However, in neighborhoods with high levels of crime, living close to a park actually depresses the value of a home (Troy and Grove 2008).

Finally, preferences for ecosystem services may be nonlinear and characterized by thresholds. In other words, more is not always better. For example, increases of tree canopy cover in Baltimore led to increased environmental satisfaction up to a threshold of about ˜60%, above which environmental satisfaction no longer increased.

In sum, we increasingly understand and appreciate the existence and importance of ecosystem services in urban areas. However, we are only beginning to understand the dynamics of human responses to variation in these services. Understanding these dynamics is crucial for understanding the push–pull drivers of urban ecosystems and their resilience over time (Borgstrom et al. 2006).

Management of Complex Adaptive Systems

Cities rarely are the result of grand master plans. Rather, they often exhibit emergent properties that are the result of bottom-up processes driven by diverse interests, agencies, and events (Jacobs 1961, Johnson 2001, Shane 2005, Johnson 2006, Batty 2008, Grimm et al. 2008). Given the bottom-up nature of these processes and emergent properties, it is remarkable how similar cities tend to be in their functions (Batty 2008, Grimm et al. 2008).

Polycentric governance (see Chapter 4) among different types of organizations—government agencies, NGOs, and CBOs—and across scales often exist. These networks tend to focus on a specific issue or interest: the stovepipes that are part of Yaffee's recurring nightmares. The ability of polycentric governance networks to contribute to urban resilience depends upon their capacity to (1) address the essential interdependence of demographic, economic, social, and ecological challenges and solutions that cities face; (2) plan for the long term within the context of uncertainty and change; and (3) adjust governance structures to meet changing needs (see Chapter 5). This requires the ability to sense and interpret patterns and processes at multiple scales. At a local scale, there is a growing trend among city governments to develop GIS-based systems that monitor a wide range of indicators in nearly real-time. For instance, a number of US cities have developed **CitiStat-type programs** that provide accurate and timely intelligence, develop effective tactics and strategies, rapidly deploy resources, and facilitate follow-up and assessments (http://www.baltimorecity.gov/news/citistat/).

New York City has taken the CitiStat approach to a new level with its 311 system. The 311 system functions in three ways, citizens reporting problems to the city, citizens requesting information about city services, and as a mutually learning system that builds upon the first two functions. The novel idea behind the service is that this information exchange is genuinely two-way. The government learns as much about the city as the 311 callers do. In a sense, the City's 311 system functions as an immense extension of the city's perceptual systems, harnessing millions of ordinary "eyes on the street" to detect emerging problems or report unmet needs (Johnson 2006).

New York City's 311 approach makes manifest two essential principles for how cities can generate and transmit good ideas. First, the elegance of technologies like 311 is that they amplify the voices of local amateurs and "unofficial" experts and, in doing so, they make it easier for "official" authorities to learn from them. The second principle is the need for lateral, cross-disciplinary flow of ideas that can challenge the disciplinary stovepipes of knowledge, data, interests, and advocacy associated with many government agencies, NGOs, and the training of professionals (see Chapters 4 and 5). This second principle is increasingly realized by the polycentric and interdisciplinary nature of sensing and interpretation facilitated by the Web and new forms of amateur cartography built upon services like Google Earth and Yahoo! Maps. Local knowledge that had so often remained in the minds of neighborhood residents can now be translated into digital form and shared with the rest of the world. These new tools have begun to unleash a revolution in the exchange and interpretation of data because maps no longer need to be created by distant professionals. They are maps of local knowledge created by local residents. And these maps are street-smart and multimedia. They can map blocks that are not safe after dark, playgrounds that need to be renovated, community gardens with available plots, or local restaurants that have room for strollers. They can map location of trees, leaking sewers, and stream bank erosion. These tools enable locals to map their local history as well—where things were or what things were like—creating and sharing long-term, local knowledge (Johnson 2006).

The scale of these observations can broaden from a neighborhood to an entire planet as these local data and knowledges become networked. Formal examples of these types of systems already exist. Public health officials increasingly have global networks of health providers and government officials reporting outbreaks to centralized databases, where they are automatically mapped and published online. A service called GeoSentinel tracks infectious diseases among global travelers and the popular ProMED-mail email list provides daily updates on all known disease outbreaks around the world (Johnson 2006). Although these types of systems are intended to be early warning systems on specific topics, they are likely to become interdisciplinary as the interdependence of challenges and solutions are recognized and facilitate comparisons and learning among both official and unofficial experts.

Summary

Cities continue to be tremendous engines of wealth, innovation, and creativity. They are becoming something else as well: engines of health that are both public and environmental, Sanitary and Sustainable. Two great threats loom over this new millennium: global warming and finite supplies of fossil fuel. These two threats may have massively disruptive effects on existing cities in the coming decades. They are not likely to disrupt the macro-pattern of global urbanization over the long term, however (Johnson 2006). The energy efficiencies of cities can be part of the solution for both global warming and energy demands.

The long-term challenges that cities face are social, ecological, and interrelated, including the growth and aging of urban populations; aging infrastructure and incorporation of adaptive technologies; environmental changes and resource limitations; and governance problems, particularly inequality. These challenges *and* their solutions are completely interdependent: sustainability and economic growth can be complementary goals (Chan 2007).

However profound the threats are that confront us today and for the near future, they are solvable (Johnson 2006). It will require approaches that perceive cities as complex, dynamic, and adaptive systems that depend upon interrelated ecosystem services at local, regional, and global scales. Polycentric governance networks will contribute to urban resilience depending upon their adaptive capacity to (1) address the essential interdependence of demographic, economic, social, built, and ecological challenges and solutions that cities face; (2) plan for the long term within the context of uncertainty and change; and (3) adjust governance structures to meet changing needs. This will increasingly involve the ability to sense and interpret patterns and processes at multiple scales. Tools that harness diverse local knowledges and "eyeballs on the street" to engage in genuine exchanges and evaluations of information will become less novel and more routine. The exchange of knowledge among cities will be important on a global basis, as we learn that there are multiple pathways to similar solutions for resilient cities that are ecologically sustainable, economically dynamic, and socially equitable.

Review Questions

1. Are the populations of cities growing more rapidly than the global population? Is this likely to continue indefinitely? Why or why not?
2. In what ways are cities similar to or different from social–ecological systems that have lower population density?
3. Are urbanization and the shift from the Sanitary to the Sustainable City directional changes? Why or why not?

4. How might demands for ecosystem services be similar and different in urban versus less densely settled areas?
5. In what ways is the transition from an "ecology *in* cities" to an "ecology *of* cities" important to understanding cities as open and multiscalar?
6. In what ways does expanding urbanization influence ecological vulnerability, resilience, and efficiency of resource use on a local, regional, and global basis?
7. Evaluate the claim that cities can provide essential solutions to the long-term social–ecological viability of the planet given population trends for this century. How is this true or not true?
8. What are some of the social challenges and opportunities to developing resilient cities?

Additional Readings

Batty, M. 2008. The size, scale, and shape of cities. *Science* 319:769–771.

Grimm, N., J.M. Grove, S.T.A. Pickett, and C.L. Redman. 2000. Integrated approaches to long-term studies of urban ecological systems. *BioScience* 50:571–584.

Grimm, N.B., S.H. Faeth, N.E. Golubiewski, C.L. Redman, J. Wu, et al. 2008. Global change and the ecology of cities. *Science* 319:756–760.

Johnson, S. 2001. *Emergence: The Connected Lives of Ants, Brains, Cities, and Software*. Scribner, New York.

Northridge, M.E., E.D. Sclar, and P. Biswas. 2003. Sorting out the connection between the built environment and health: A conceptual framework for navigating pathways and planning healthy cities. *Journal of Urban Health: Bulletin of the New York Academy of Medicine* 80: 556–568.

Pickett, S.T.A., M.L. Cadenasso, and J.M. Grove. 2004. Resilient cities: Meaning, models and metaphor for integrating the ecological, socio-economic, and planning realms. *Landscape and Urban Planning* 69:369–384.

Pickett, S.T.A., P. Groffman, M.L. Cadenasso, J.M. Grove, L.E. Band, et al. 2008. Beyond urban legends: An emerging framework of urban ecology as illustrated by the Baltimore Ecosystem Study. *BioScience* 58:139–150.

Spirn, A.W. 1984. *The Granite Garden: Urban Nature and Human Design*. Basic Books, Inc., New York.

F. Stuart Chapin, III
Gary P. Kofinas
Carl Folke

Principles of Ecosystem Stewardship

Resilience-Based Natural Resource Management in a Changing World

Illustrated by Melissa C. Chapin

Springer