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REVIEW PAPER

# Incorporating critical elements of city distinctiveness into urban biodiversity conservation

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**Abstract** The conservation of biological diversity is closely linked with the fate of the world's cities. While the protection of sensitive and threatened species and habitats has often taken place in natural landscapes largely devoid of people, strategies for preserving the Earth's biodiversity that can be employed within cities are likely to become more common as urban areas continue to increase in size and number. Progress towards the development of effective conservation methods for working in urban areas is impeded by several factors, including the unfamiliarity that many conservation scientists have with urban landscapes, and the need to identify and incorporate elements of an urban area's distinctiveness into biodiversity conservation projects. Even cities of the same size differ significantly in terms of their bio/geo/ecological realm or "natural" environment, their human communities, and their built environment, and these differences matter for the development of urban conservation strategies. Conservation practitioners can effectively incorporate information about these differences into their implementation efforts by: using a robust adaptive management framework that allows for an iterative approach in the development of strategies, employing the ecosystems concept when working in project areas that include urban spaces, incorporating pre-existing socioeconomic data into urban conservation planning, and harnessing technological and other resources readily available within urban areas to meet the needs of biodiversity conservation practitioners.

**Keywords** Urban · Planning · People · Historical ecology · Metropolitan area · Human population

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## Introduction

Conservation of biological diversity is closely linked with cities, as urbanization has significant consequences for protected areas (McDonald et al. 2008). Because many large, fast-growing cities and over 20 % of the world's population can be found within existing biodiversity hotspots (Cincotta et al. 2000; Balmford et al. 2001), the future of urban places will profoundly impact biodiversity on a global scale (McKinney 2002). With over half of the world's population currently living in cities (UN-HABITAT 2008), including 80 % of people in the United States, there are more urban dwellers now than ever before, and rapid urbanization is one of the planet's most notable trends in land use. Urban areas engulf native plant and animal communities, and use water, energy, and raw materials that originate from hinterlands much larger than the footprint of the city itself (Cronon 1991; Wackernagel et al. 1999). While the location, form, and function of future cities could provide an opportunity for improving human well-being (Project for Public Spaces 2012), there is also growing concern about the lack of interaction of urban dwellers with nature (Louv 2005; Miller 2005), and the lack of interest amongst the public, especially younger generations, in environmental topics (Twenge et al. 2012).

To protect sensitive species and habitats from the threats posed by human activities, the conservation planning literature and many biodiversity conservation efforts have focused primarily on preserving natural landscapes in areas without many people (Soulé and Terborgh 1999). However, some argue that biodiversity conservation strategies must diversify beyond this type of work to successfully maintain the Earth's biodiversity in a future containing many more people and including many new urban areas (Miller and Hobbs 2002; Koh and Sodhi 2004). A groundswell of interest in "urban conservation" has developed within the biodiversity conservation community (Goddard et al. 2010), prompting large organizations such as The Nature Conservancy to ask what role urban-focused strategies will have within the larger realm of biodiversity conservation work over the next twenty years (The Nature Conservancy [TNC] 2013).

The variety of conservation challenges posed by urbanization has led to the development of a diverse suite of urban conservation strategies. These include efforts by conservation practitioners to preserve biodiversity within cities (Rudd et al. 2002; Alvey 2006), protect key natural areas that provide the resources and ecosystem services upon which cities depend (Postel and Thompson 2005), conserve resources within cities to reduce the city's ecological footprint and enhance sustainability (Wackernagel et al. 2006), and garner support for conservation efforts from urban-dwelling constituencies through educational outreach (Dearborn and Kark 2009). In order to untangle this complex realm of conservation planning, strategy, and implementation, conservation scientists have begun to develop a succinct contextual framework for understanding the motivations and expected outcomes of the various efforts categorized as urban biodiversity conservation (JM Randall, SA Morrison, and SP Parker unpublished data). This framework builds upon ongoing research investments and a rapidly growing literature focused on urban ecology and urban ecosystem science (Pickett et al. 2012). With this conceptual framework in place, the full power of science-based conservation planning, strategy development, and expert implementation could be brought to bear in urban conservation projects.

Unfortunately, there are some problems—having worked largely in natural areas, many conservationists are unfamiliar with how to interpret urban landscapes (McDonnell 2011). Given that a gap can exist between conservation theory/planning and conservation practice/implementation (Prendergast et al. 1999; Knight et al. 2008; Reyers et al. 2010), the growing scientific literature that describes and defines the ecology of cities (Pickett et al.

2001; Alberti et al. 2003; Marzluff et al. 2008; Forman 2014) has been embraced by conservation practitioners and realized through comprehensive urban biodiversity projects on the ground in only some of the world's urban areas (Adams 2005). Despite studies that demonstrate that certain portions of urban areas can have high quality habitat for species of conservation concern (Gustafsson 2002) and high levels of species richness (Kuhn et al. 2004), many maps used by conservation practitioners still designate urban areas as uniformly devoid of habitat. In addition, while there are similarities between urban areas, fundamental differences in ecology, built environment, demography, history, and culture serve to distinguish a unique set of observable characteristics for each city. Conservation practitioners must consider what elements of the urban environment should be included in the development of conservation strategies to protect biodiversity and engage in conservation programs for the specific city where they are working. What follows here is a guide for identifying elements of an urban area's distinctiveness that should be considered when planning for and implementing biodiversity conservation within it.

## Definition of terms: what is an urban area?

The first challenge for conservation practitioners in planning for biodiversity conservation within the urban realm is to gain some familiarity with the existing lexicon used to describe urban areas. Systematic, science-based conservation planning traditionally involves the categorization of natural systems based on a clear ecological taxonomy. Though many conservationists may be unfamiliar with it, a similar taxonomy for describing urban areas has been adopted by social scientists and governments. By learning more about the various urban classification systems used around the world, conservation practitioners can avoid confusion about the geographic scope of their urban-focused work when discussing it with a broad audience (Table 1). It is important to note that a standardized categorization of urban areas has not yet been adopted globally; for example, the 228 United Nations member states employ at least 10 categories of urban classification based on combinations of population size and density, administrative boundaries, and economic activities (Utzinger and Keiser 2006). One system for classifying urban areas that may be particularly informative for informing conservation strategies is the "human modification framework" developed by Theobald (2004), which characterizes landscapes on a quantitatively-defined gradient from urban lands to wildlands based on human population density, the degree to which natural processes are unaltered or controlled by human activities, and the presence of natural versus artificial landscape patterns. This framework may be particularly useful in the early stages of an urban conservation program, when other successful programs that are underway or have been completed in similarly-categorized landscapes may provide useful guidance to conservation practitioners.

## Not all urban areas are created equal

With a hierarchical taxonomy in place for categorizing urban areas, another challenge emerges—even cities of similar population size and/or land area can be very dissimilar in other respects. Despite the fact that urban areas have a sufficient number of shared land use characteristics that they can be categorized as urban rather than some other land use, they vary greatly. While the skyline of a city or its important economic activities may be its most identifiable traits to many people, differences between cities include other physical,

**Table 1** Some of the common terms used to describe the geographic scope of cities and greater metropolitan urban areas are illustrated using examples from Los Angeles, California, USA; São Paulo, Brazil; and London, UK

| Term | Definition | As applied to… | | | | | |
|---|---|---|---|---|---|---|---|
| | | Los Angeles | | São Paulo | | London | |
| | | population | area ($km^2$) | population | area ($km^2$) | population | area ($km^2$) |
| City proper | an urbanized place that has a distinct name and political boundary | City of Los Angeles | | São Paulo | | City of London; "The City" | |
| | | 3.8 million[1] | 1,302 | 11.9 million[2] | 1,521 | 7,375[3] | 2.90 |
| Metropolitan (metro) area | A statistical unit used by government census authorities; composed of the counties or municipalities comprising an urban core, as well as surrounding urban areas that are tightly linked through socioeconomic connections | Metropolitan/Greater Los Angeles; "The Southland" | | Metropolitan/Greater São Paulo; Região Metropolitana de São Paulo | | Greater London | |
| | | 12.8 million[1] | 12,520 | 20.3 million[2] | 7,944 | 8.2 million[3] | 1,569 |
| Urban agglomeration/ conurbation/ megacity | A region comprised of a number of cities and towns that have merged into one urban area due to population growth and physical expansion; a *conurbation* is a polycentric urban agglomeration, in which an urban labor market is linked through transportation; a *megacity* has at least 10 million inhabitants | Los Angeles-Long Beach-Riverside Combined Statistical Area | | Extended/Expanded Metropolitan Complex of São Paulo | | Greater London Built-up Area; Greater London Urban Area | |
| | | 17.9 million[1] | 87,490 | 27.6 million[2] | 23,062 | 9.8 million[3] | 1,738 |
| Megalopolis/ megopolis/ megaregion | A loosely clustered network of adjacent metropolitan areas with a population of at least 10 million people[4], the transportation infrastructure between urban centers not developed to allow for daily travel to work between all of the included metropolitan areas, though less-frequent travel is common | Southern California Megalopolis | | Rio-São Paulo Megalopolis | | European Megalopolis; "Blue Banana"; Manchester-Milan Axis | |
| | | 24.9 million[5] | 146,366[5] | 45.7 million[5] | ~31,000[5] | 110 million[5] | ~515,000[5] |

[1] U.S. Census Bureau 2010

[2] Instituto Brasileiro de Geografia e Estatistica [IBGE] 2014

[3] Office for National Statistics [ONS] 2013

[4] Gottmann 1961

[5] Area and population estimated by drawing a polygon around semi-contiguous urbanized landscape in each region and summing up populations of included urban areas

biological, cultural, sociopolitical, and economic traits which combine to create a unique geo/bio/socioeconomic landscape.

Many of the dissimilarities between different urban areas are obvious to the casual observer. For example, tree cover varies greatly both between cities (Nowak et al. 2001), and within cities (Jim and Liu 2001; Heynen et al. 2006; Clarke et al. 2013), and both reflects and impacts patterns in human health and socioeconomic status (Martin et al. 2004; Donovan et al. 2013). Conservationists working in urban areas can benefit from viewing cities as a palimpsest, a rich layering of nature's imprint in addition to human habitation and land use. With this model in mind, urban distinctiveness, or the unique suite of characteristics that distinguish one urban place from another, can provide important guidance for structuring biodiversity conservation efforts.

## Factors of urban distinctiveness

An urban area's distinct traits strongly influence the conditions that a conservation practitioner encounters when putting together an urban conservation strategy. Distinctiveness factors can be sorted into three main categories: (1) the bio/geo/ecological realm or "natural" environment where conservation practitioners typically focus, (2) the human realm, and (3) the built environment. These three factors interact with one another within urban areas, and in the hinterlands associated with urban areas, thereby shaping the properties and processes that distinguish one urban area from another, with consequences for biodiversity conservation. Since the launching of National Science Foundation-supported Long Term Ecological Research sites in the cities of Phoenix, Arizona and Baltimore, Maryland in 1997, there has been a growing interest within the field of ecology to build a better understanding of the interaction between various ecological, physical, and sociological components of urban areas (Pickett et al. 2001; Alberti et al. 2003), and to reveal universal ecological principles and apply them to ecological landscape design within urban spaces (Cadenasso and Pickett 2008; McGrath and Pickett 2011). However, some of these efforts stop short of including a discussion of biological diversity, which, as one of the more complex and potentially altered characteristics of the natural environment in cities, stands out as a priority for urban conservation planning and implementation.

Using examples from cities around the world, the following discussion illustrates how urban areas differ from one another, how distinct places within cities can vary greatly, and how those differences may be conservation-relevant.

## The natural environment

Urban areas are relatively new when compared with the natural environments in which they are embedded; the first Mesopotamian city was not established until approximately 7,000 years ago. Prior to the development of urban areas, ecological processes across the landscape were largely controlled by an array of physical and biological factors, with humans typically playing a less dominant role in driving these processes than they do currently. While humans certainly modified landscapes prior to the advent of cities, chiefly by hunting and through the use of fire (Timbrook et al. 1982; Bowman 1998) and agriculture (Delcourt 1987), these impacts were in general less intense than those associated with subsequent urbanization.

Once a city is established, the natural history of the area may be somewhat obscured through intense human modifications. In trying to understand a city's underlying ecology, a useful starting point is to imagine what the landscape may have looked like and how it functioned before the city existed (Cunningham 2010). This may be difficult in locations that have been densely urbanized for millennia. However, there are some areas where cities did not develop until European contact was made, despite these areas having had a long history of human habitation. For example, the heart of downtown Sydney, Australia, which is now dominated by buildings, roads, and parks, was once native woodland consisting of tall red gum (*Eucalyptus* spp.) and cabbage palms (*Livistona australis*) with an understory of wattles (*Acacia* spp.) and banksias (*Banksia* spp.) (New South Wales National Parks and Wildlife Service [NSW-NPWS] 2003). Though Aboriginal people had lived in Sydney cove for 200,000 years, a city did not begin to develop there until Europeans arrived in the late 1700s, and there is a detailed written record of the pre-contact landscape. Historical ecologists use records such as these to generate a better understanding of what a landscape was like prior to being heavily modified by human activities by creating descriptive maps of the native vegetation, soils, surface water, and other features in areas that are now urbanized (Beller et al. 2011; Dark et al. 2011). They may also gather information about the native plant and animal communities that were once found within an area, and the physical processes that supported them. Along with data collected from nearby undisturbed locations, this information can be used establish the reference conditions for the ecosystem in question (Nestler et al. 2010). This knowledge can help conservation practitioners set restoration goals and decide, for example, to what endpoint a degraded and denuded riparian floodway could feasibly be restored, and what elements of native biodiversity can be incorporated into revitalized urban ecosystems (Swetnam et al. 1999). While the reference condition for an ecosystem can provide a valuable contextual background against which the benefits of restoration can be measured, it is important to note that urbanization can alter the ecological and physical processes in a system, and make it impossible for the species that once lived there to be self-sufficient in the future (Bernhardt and Palmer 2007).

In all stages of urban development, human endeavors continue to be imbedded in the larger economy of nature (Callicott et al. 1999). As humans alter the landscape through the construction of urban areas, some of these natural factors change, creating a feedback loop between the urban landscape and its human inhabitants. The factors that control the ecology of a place are familiar to conservation scientists, whose training is often within the life sciences. These include, but are not limited to, the area's climate, disturbance ecology, paleoecology, topographical variability, water availability, geology and soils, dominant vegetation types, biodiversity, and susceptibility to climate change. Understanding the climate and typical flood/fire return interval for the region in which a city is embedded can help conservation practitioners select species of plants that will thrive in an urban restoration project. In addition, understanding soil properties and processes can help a project team determine if urban soils provide the necessary fertility, texture, and stability for the growth of target plant species they are attempting to protect or restore in an urban landscape (Pavao-Zuckerman 2008). Soils knowledge is also useful for determining if the ecosystem services that soils provide in natural systems, such as carbon storage, water filtration, and regulation of gas production and decomposition, have been compromised.

Patterns in urban growth provide clues that can guide conservationists towards new geographies that may not be currently threatened by intense urbanization pressure, but could be under greater threat in the future. The growth of urban areas is constrained by local geography and topography, with mountains and bodies of water acting as natural barriers to growth. Some cities, such as Chicago, have no mountains nearby, and could conceivably grow for tens to hundreds of miles in all directions away from Lake Michigan to be as large as is economically viable (Fig. 1). As a result, the largest megalopolis in the United States is not found in southern California or the Northeast, but in the Great Lakes region; it includes Chicago, Milwaukee, and Detroit, among other cities. Landscape features such as waterways that draw rich conglomerations of plants and animals also provide resources for large human communities, which may explain why many urban areas are located near water and in biodiversity hotspots (Cincotta et al. 2000). These biodiversity hotspots (Myers et al. 2000) occur throughout the world. Where they co-occur with urban areas, conservationists must develop specific strategies for engaging in the urban realm in order to ensure that biodiversity is retained in these places. A few of these strategies are highlighted below.

Often, biodiversity conservation that is done in, by, and for cities delivers significant benefits to people in the form of ecosystem services. In particular, a variety of nature-based solutions have been developed to protect urban areas from the effects of climate change (Beatley 2009). Biodiversity conservation strategies that result in co-benefits to humans through nature-based climate change adaptation make these strategies particularly promising in urban areas. While all cities have some degree of susceptibility to climate change, being able to recognize patterns in this susceptibility, and propose nature-based solutions to the threats posed to humans by climate change, can help conservation practitioners to identify projects that both benefit urban populations and protect biodiversity. For example, urban areas along the coast, especially those near estuaries and river mouths, are particularly vulnerable to climate change in the form of sea level rise and flooding. In some cases, the buffering effect of wetlands that would have mitigated climate change impacts must somehow be recreated to provide these services (Beck et al. 2011). One way to do this is to protect and enhance existing natural wetlands along the coast through the restoration of oyster reef habitat. This restoration has occurred with some success in several sites along the Atlantic seaboard and Gulf of Mexico in the United States (Brumbaugh and Coen 2009), and in Strangford Lough in Northern Ireland (Smyth et al. 2009).

The raw materials required to support a city and its inhabitants can be derived from thousands of miles away (Cronon 1991; Collins et al. 2000), and with the development of long-distance conveyance infrastructure for water, energy, and materials, the resource footprint of cities has grown over time. For example, the 8 million inhabitants of Bogota, Columbia receive water from a series of high-elevation, protected wetland watersheds (Postel and Thompson 2005). Even in cases where urban areas are dependent on the watersheds in which they are embedded for the provisioning of freshwater, the political boundaries of cities, and extent of urbanized land cover, may not correspond well with watershed boundaries. New York City determined early on that protecting the city's watershed hinterlands would be much less costly than building an artificial filtration system to provide clean drinking water for the city's inhabitants. In the 1990s, efforts were taken to ensure that the watershed remained in forest to protect the quality and quantity of the city's water supply (Featherstone 1996).

Despite the losses in native biodiversity that occur through urbanization (McKinney 2002), cities can continue to harbor habitat fragments that have conservation value and that reflect the underlying natural environment. Native trees that are retained during development can serve as part of an urban forest, providing habitat for birds (Guthrie 1974; White et al. 2005; Chace and Walsh 2006) and arthropods (McIntyre 2000), and providing ecosystem services such as rainfall interception, air purification, and insolation reduction to people in cities (McPherson et al. 2005). The biodiversity values found in cities can be augmented through habitat enhancements, such as the recontouring of previously


**Fig. 1** Comparably-scaled maps of three cities: Cape Town, South Africa (**a**); Chicago, Illinois, USA (**b**); and Milan, Italy (**c**); depicting nearby water bodies (*blue*) and mountains that limit the current extent of urban development (*gray*), and the potential for future contiguous urban expansion on flatter lands nearby (*white*). (Color figure online)

channelized streams and replanting of riparian vegetation, and through urban greenscaping efforts such as the development of rooftop and backyard gardens that create pollinator pathways through the city (Matteson et al. 2008). Ecosystem processes that have been interrupted through changes in the built environment can be at least partially restored through green retrofitting, such as through the replacement of impermeable street pavement with more permeable surface materials that allow for increased water infiltration during storms (Scholz and Grabowiecki 2007).

Studies of native biodiversity within cities can provide a glimpse into a region's less urban past, and inspiration for future habitat restoration. However, conservationists must consider potential downsides to the preservation of native species in an urban context. For example, while many populations of native plants and animals—even large mammals—can be found in urban environments (Rubin et al. 2002; Spinks et al. 2003; Bland et al. 2004; Gehrt 2007), an urban population of a species may not necessarily be healthy (Gliwicz et al. 1994), and it has the potential to negatively impact the more wild populations of a species regionally. Conservationists must consider, for example, whether an urban environment presents ecological traps (Schlaepfer et al. 2002), or if disease transmission between plants (Poland and McCullough 2006) or animals (Bradley and Altizer 2007) would be a concern for urban and rural populations of the species and communities they are working to protect. Potential negative impacts are species specific, so the overall suitability of an urban environment for the preservation of a native plant or animal population must be assessed on a case-by-case basis (Luniak 2004).

## The people

Since ancient times, and the size, structure, and distribution of human communities on the landscape has occupied a key position in the minds of civic leaders and social scientists (Missiakoulis 2010). The myriad applications of social science to urban conservation efforts are too copious to define and describe in exhaustive detail here, but it is worthwhile to highlight basic information from the fields of sociology, economics, and political science that may prove useful in developing urban conservation strategies.

Human population size is the most basic demographic measure of an urban area, and can vary between urban areas by several orders of magnitude. Conservation strategies that may be effective in a community of 150,000 individuals such as Cambridge, U.K., may feel like a drop in the bucket if deployed in an urban area 50 times that size, such as the

Greater London Urban Area. Trends in population growth can be complex—for example, a city proper can shrink in population size while the metropolitan statistical area grows in population. This is true of several urban areas in the American Midwest, such as the St. Louis area. Unfortunately, changes in factors that may matter to conservationists don't necessarily scale well with an urban area's population size alone. Other factors such as the age, gender, ethnicity, national origin, religious affiliation, income, etc. of an urban area's inhabitants can have a strong influence on how urban conservation strategies will work, because different groups have different needs and interests. To complicate matters, the demographics of urban areas change over time due to changes in immigration, births, and deaths. As these vital statistics can vary between groups, the human face of urban areas is constantly changing. Thus, conservationists must use current data about the human inhabitants of a city in order to develop successful urban conservation strategies.

Early settlers can exert a strong cultural influence over an area for centuries, leading to distinct regional differences in culture (Woodard 2011). The distinct cultural values that develop over a city's history can inform the human community's perceptions of environmentalism and conservation (Berg and Dasmann 1977), and have an influence on conservation success today (Waylen et al. 2010). In an example from North America, habitation by native people dates back at least 15,000 years (Goebel et al. 2008). Many sites of Pre-Columbian cities, towns, and gathering places became European settlements during successive waves of colonization that began in 1492. One such location was Tenochtitlán, which was originally built by the native Aztec people in 1325, grew to be the largest city state in the pre-Columbian Americas, and was partially destroyed and rebuilt by the Spanish as Ciudad de México (Mexico City) beginning in 1521 (Hassig 1994). Both Spanish and Aztec heritage are evident in the city's current ethnic make-up, languages, and culture—a legacy that endures to this day. What also endures are remnants of the canal and chinampa ("floating garden") agricultural system developed by the Aztecs prior to Spanish occupation (Torres-Lima et al. 1994), and a variety species, such as the axolotl (*Ambystoma mexicanum*), that depend on this human-constructed system for their survival in the wild (Contreras et al. 2009). The conservation of sensitive and rare species such as the axolotl is intimately tied with an effort to restore portions of Mexico City's agricultural space to its Pre-Columbian form and function in Xochimilco Ecological Park (Wirth 1997), an endeavor that has developed over the past two decades in concert with a broader societal recognition of the cultural heritage and rights of indigenous peoples in Mexico (Muñoz 2005).

Various facets of culture can influence the human community's perceptions about conservation. For example, religions differ greatly in their views about the relationship between humans and the natural world. The religious make-up of cities varies, but can be strongly influenced by religious migrations of the past. For example, Mormons founded Salt Lake City in the Utah territory in 1847; though the city has grown to 30 times its original size, members of the Church of Latter Day Saints still comprise 45 % of the city's population (Public Broadcasting Service [PBS] Experience 2007). The religious beliefs held by urban dwellers may influence how willing a city's populace may be to support conservation. Influential science historian Lynn White proposed that the root cause of the post-industrial environmental crisis was an anthropocentric Christian value system based on the idea that humans have control over the natural world (White et al. 2005). More recently, conservative religious traditions, commitments, and views about death, the afterlife, and the ultimate fate of humanity have been found to strongly impact environmental perspectives of study subjects (Guth et al. 1995). Taking this a step further, Sherkat and Ellison (2007) found that religious affiliation and participation can have direct effects not just on environmental concern, but also on the study subjects' participation in personal and political environmental action. All of these factors may have consequences for a city's support of conservation efforts.

In addition to religion, political parties and issues also play a role in determining how human communities interact with the natural environment. Coffey and Joseph (2013) have found in a study of individual recycling and conservation behavior that pro-environmental behaviors are closely associated with partisan and ideological dispositions. Relationships between the community and authority, and the past interest, involvement, and political prominence of conservation and the environment can be important as well. Conservation projects must conform to government policies, and government support and enabling legislation for conservation varies greatly from one city to the next, with some urban areas investing heavily in urban parks and wildlife. Conversely, some governments have a legacy of indifference, apathy, or even antagonism towards biodiversity conservation efforts. In an example from Seoul, Korea, the city government and the conservation community held different ideological opinions about the purpose of a £200 million Cheonggyecheon stream restoration in the city's urban center, resulting in a controversial outcome (Cho 2010).

A city's economic status may be important to understand when crafting an urban conservation strategy, as income disparities are closely linked with biodiversity loss (Mikkelson et al. 2007). Differences in human wealth among the regions of the world correspond well with geographical biases in the science literature (Pyšek et al. 2008), with more studies being conducted in wealthier regions. Regional differences in the financial support for, political interest in, and public awareness of conservation science could have a major impact on the questions posed, systems studied, and efforts made on the ground to protect or enhance biodiversity within urban areas.

## The built environment

A city's built environment constitutes the third category of urban distinctiveness. As was the case with a city's people, it is beyond the scope of this discussion to describe all of the myriad applications of landscape architecture and urban studies to conservation efforts. However, by highlighting some of the basic information that can be gleaned from these disciplines for contextualizing the built environment of cities, one may begin to appreciate how understanding these factors may prove useful in developing urban conservation strategy.

The infrastructure of cities can be viewed as an ecological phenomenon in and of itself (Banham 1971). Infrastructure can serve to enhance or sever connectivity between habitats and human communities within the city, and between the habitat within city and its surrounding hinterlands. The built environment of cities is strongly influenced by economic status, prevailing aesthetic concerns, and the technology available during each phase in a city's development. Transportation technology has influenced all elements of city infrastructure, guiding patterns in housing density and neighborhood development over time. The date of a city's founding and first period of rapid growth play a strong role in structuring development patterns, but over time, the changing conditions, needs, and culture of the human populace re-create the built environment, generating a rich palimpsest where new overwrites old. For example, the fertile Yangtze Delta area of China has long been a densely populated and intensely farmed landscape, but patterns in urban growth have rapidly changed in this region as single family homes and cars have become

**Table 2** Six strategies for conservation practitioners working in urban areas

| Strategy | Explanation |
|---|---|
| Employ adaptive management | Use a robust conservation planning framework that allows for continual refinement of conservation strategies |
| Embrace the ecosystems concept | When defining the scope of an urban conservation planning area, pay special attention to ecological pattern/process |
| Abandon the gray/green dichotomy | Incorporate gradations in the suitability of urban habitat for various species into project maps |
| Use socioeconomic/cultural factors in planning | Use pre-existing surveys of human communities' perceptions of nature to help guide implementation and educational outreach |
| Understand and engage with power | Strong ties with government, NGOs, and the public can go far towards advancing conservation strategies |
| Make use of technology | Collection of some data can be easier in cities because of the ubiquitous presence of mobile telecommunications applications and citizen science |

increasingly common in recent years (Wu et al. 2009). Shifts in the density and pattern of the built elements of the landscape can have consequences for ecological connectivity, migrations, and dispersal through cities (Bierwagen 2007).

The infrastructure of cities varies in obvious ways. Differences in the age, architectural style, or density of a city's built features can have consequences not only for human inhabitants, but for other species impacted by the city and its activities as well. In general, older areas within cities have the highest likelihood of undergoing passive re-vegetation through natural succession, though this can take a long time depending on environmental factors (Webb et al. 1986, 1987; Weisman 2007). In contrast, newer urban areas are less likely to support native species, unless open space preserves have been planned and managed for conservation values. Few new urban developments explicitly incorporate landscape features and construction elements that support native species. As a result, newer infrastructure typically harbors little native biodiversity.

Native species can be attracted to the infrastructure provided by urban bridges and buildings. For example, the unintentional colonization of the Congress Bridge in Austin, Texas by Mexican free-tailed bats (*Tadarida brasiliensis*) has provided a powerful nexus for environmental education and tourism, broadly enhancing bat conservation efforts (Pennisi et al. 2004). Finding these opportunities for "reconciliation ecology" (Rosenzweig 2003) within the built environment can provide conservationists with a useful urban platform for launching conservation efforts beyond the city boundaries. In many cases, however, urban infrastructure alters the natural environment enough that it cannot support native species. Retrofits of infrastructure or preserves that set aside natural areas may be needed to support species of conservation concern within city limits. Because urban ecosystems typically include a mix of native and non-native species, the work of conservation practitioners would be aided by viewing cities as novel ecosystems, each with its own suite of species, ecological processes, and management needs (Hobbs et al. 2006).

Infrastructure that enhances an urban area's greenness, walkability, and available public park space can impact the well-being (Secco and Zulian 2008) and longevity (Takano et al. 2002) of the area's human inhabitants. Recognition of the societal benefits of green infrastructure projects that support biodiversity while also managing storm water, sequestering carbon, or performing other vital functions for the city, may create a positive feedback loop between these projects and public support for conservation (Benedict and McMahon 2002).

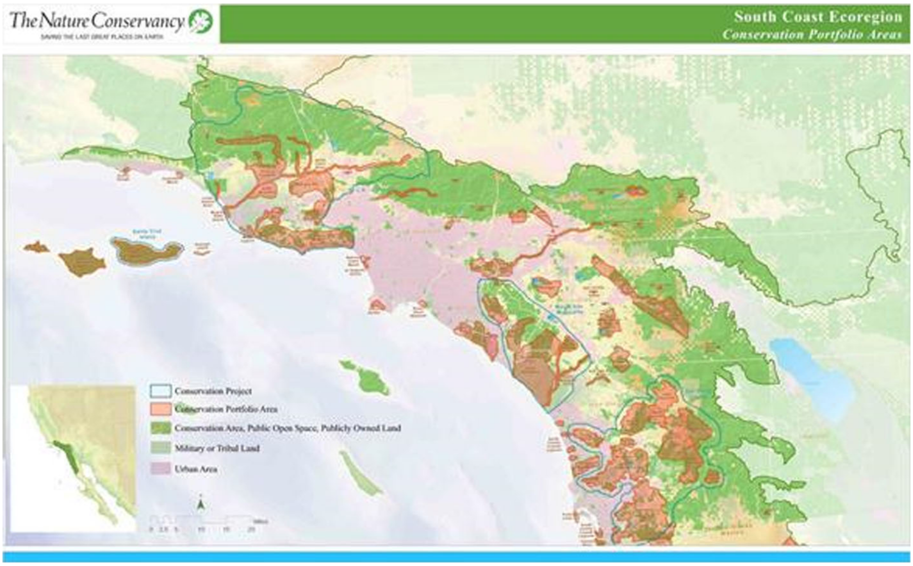


**Fig. 2** A map produced by The Nature Conservancy showing urban areas (in this case *colored pink* rather than *gray*), and protected lands (*colored green*). (Color figure online)

**Table 3** Examples of data available from various sources for incorporation into urban biodiversity conservation projects

| Data category | Data description | Example sources |
|---|---|---|
| Natural history, biological, and ecological data | Occurrence data for species | State Natural Heritage Programs |
| | Soils and geology maps | USDA Soil Survey |
| | Historical ecology studies | San Francisco Estuary Institute |
| | Footprint maps | The Nature Conservancy |
| | Citizen science efforts | ebird |
| People | Demographic data | US Census Bureau |
| Built environment | Housing density, zoning, infrastructure maps | County planning departments |

## Incorporation of urban distinctiveness into conservation planning

Conservation practitioners can use the existing strengths of systematic conservation planning to include information about urban areas into conservation work, and to develop new strategies for working in urban areas (Table 2). The development, use, and continued modification of robust conservation planning frameworks such as Conservation by Design (The NatureConservancy [TNC] 2000), allow for adaptive management and continual refinement of conservation strategies. Conservation Action Planning (The NatureConservancy [TNC] 2007) has been adopted by a variety of agencies and organizations beyond The Nature Conservancy to guide the development of strategies using a science-based approach to biodiversity conservation. With this planning framework in place, along with ongoing research efforts of scientists and restoration projects led by land managers, the challenge of developing strategies for working in urban areas is surmountable.

Conservation planning that is firmly rooted in an understanding of ecosystem ecology may be particularly important in urban settings. Biodiversity conservation efforts that focus solely on the preservation of naturally-occurring plant communities unavoidably exclude the human-dominated landscapes in cities where these natural communities are fragmented, degraded, or absent. In contrast, the ecosystem concept applies everywhere, in natural as well as human-dominated landscapes (Grimm et al. 2000). This concept can be useful in developing projects that provide ecosystem services such as water filtration or heat island reduction that are of great value to the human inhabitants of cities, and biodiversity values can then be planned for as a co-benefit of these types of green infrastructure projects (Opdam et al. 2006).

Employing an ecosystem-based approach to defining the scope of an urban conservation planning area, instead of focusing on intact plant communities and simply viewing urbanization as a threat, will be a departure for conservation practitioners who have grown accustomed to thinking of urban areas as uniformly devoid of habitat and ignoring ecological pattern/process and species occurrence data within urban “gray” zones. To this end, conservation practitioners would be well-served to abandon the gray/green dichotomy (Fig. 2) when defining the scope of a project area, and instead incorporate urban areas into their plans a novel ecosystems (Hobbs et al. 2009), with their own suite of species and ecological processes.

The importance of using socio-economic data in conservation planning is recognized by conservation planners (Polasky 2008), particularly for work in data-poor project areas (Ban et al. 2009). While the use of socio-economic data to plan for biodiversity conservation within urban areas may not be a common practice, the process of incorporating these types of data into conservation planning can begin with simple measures and predictions. Surveys of various human communities’ perceptions of nature (Vining et al. 2008) and use of neighborhood open space may be appropriate jump-off points, and in many cases these data may have already been collected by social scientists for city planning purposes. More sophisticated surveys of how these perceptions change with exposure (Shwartz et al. 2012) can help guide educational outreach by conservation groups. In-depth analyses of the social factors that impact the success of conservation in urban areas (Warren et al. 2011) are also helpful in identifying the conservation strategies that result in biodiversity protection. Garnering government support for conservation, either through broad community appeal or through the work of small but effective advocacy groups, is an essential step towards enacting conservation strategies in an urban area. Eventually, urban conservation planning could serve as an informative test ground for incorporating social science-based methods into conservation planning more broadly.

A number of key data sources exist for conservation practitioners to use in acquiring information to inform urban conservation strategies (Table 3). The Baltimore, Maryland and Phoenix, Arizona Urban Long Term Ecological Research sites have the potential to provide conservation practitioners with information about the fundamental ecological function of cities, as well as providing guidance about the practicalities of doing work in urban areas. Collection of some types of ecological data, such as species occurrences, can actually be easier in cities because of the ubiquitous presence of mobile telecommunications applications and citizen science, as exemplified by efforts such as ebird (Wood et al. 2011). Conservation planning tools are also evolving to better integrate information on wildlife habitats, connectivity, and element occurrences into land-use planning in urban areas (Gordon et al. 2009; Underwood et al. 2011).

Strategic conservation planning for biodiversity preservation in urban areas can be done successfully, and many of the tools needed to embark on this work are well-vetted and readily available. With these, and a good understanding the of the various ecological, physical, and sociological elements that constitute an urban area's distinctiveness, conservation biologists are well poised to face the challenge of preserving the earth's biodiversity, even as cities grow and natural areas become more affected by human activities.

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