Urban Biodiversity Gains New Converts

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Cities around the world are conserving species and restoring habitat.

Nature is being brought back into urban life—and that bodes well for efforts to conserve global diversity. Cities are supporting a range of efforts, including restoring watersheds; expanding and linking conserved areas; encouraging green roofs and local green gardening; reintroducing native fauna and flora to parks and walkways; removing the constructed covers over brooks, streams, and rivers (referred to as *daylighting* waterways); and encouraging educational outreach programs and green architectural design. From Stockholm and Malmo in Sweden to Copenhagen, Denmark; Curitiba, Brazil; Portland, Oregon; San Francisco; Chicago; New York City; and Singapore, cities are revitalizing the potential for biodiversity.

There is much new thinking going on. Timothy Beatley, University of Virginia professor of environmental and urban planning, extends *biophilia*—biologist E. O. Wilson's term for an inherent human affinity for other species and natural communities—to city planning. His "biophilic cities" steward and restore their natural and cultivated biodiversity. Beatley details this urban vision in *Biophilic Cities: Integrating Nature into Urban Design and Planning*. "My vision of a vibrant, compact, walkable, sustainable city has within and without it lots of nature—horizontally, vertically in all the spaces of the city," he said in an interview. New parks are being planted with native species, and many experts write about the health benefits of urban biodiversity. "With nature in the city," Beatley explains, "we are more social and healthier. Nature… is uniquely suited to bring us together."

In addition to recreation, Teardrop Park, located in Lower Manhattan and designed by landscape architects at Michael Van Valkenburgh Associates, includes 17,000 plants, most of them native species; diverse habitats, such as a miniature marsh; and connections to wildlife corridors. Photograph: Nilda Cosco, Natural Learning Initiative.

Urban biodiversity got a boost in October 2012, when the Cities for Life Summit convened for the second time. The summit was held in Hyderabad, India, in conjunction with the biannual Conference of the Parties to the Convention on Biological Diversity (CBD). Attended by over 500 people, including over 60 mayors or municipal leaders, the Cities for Life Summit showcased the CBD-requested report

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The Cities and Biodiversity Outlook (CBO). The summit also produced the "Hyderabad Declaration on Subnational Governments, Cities and other Local Authorities for Biodiversity," highlighting the role of cities in implementing the CBD's biodiversity agenda. The larger CBD meeting included a focus on cities, supported follow-up work, and recognized the contribution of the Cities for Life Summit.

Urban biodiversity was also brought to public attention from an unexpected quarter: the aftermath of Hurricane Sandy. The storm's devastation renewed public concerns over climate change. Scientists sought to emphasize the connection between urban vulnerability to climate change and biodiversity. "With Hurricane Sandy, we really see the crucial importance of urban ecological areas," explains NASA and Columbia University climate scientist Cynthia Rosenzweig, who also cochairs the New York City Panel on Climate Change. "As we plan for… the possibility of more extreme weather events, we must embrace and enhance biodiversity, because urban ecology has a very important role to play in the city's responding to climate change."

Biodiversity in the city: Perceptions and fundamentals

Urban biodiversity is often misunderstood as a kind of morphed nature with its own rules. "One key misunderstanding is that biodiversity in cities is urban biodiversity, but biodiversity is biodiversity; that diversity of life is wherever you are," explains ecologist Elizabeth Johnson, who manages the Metropolitan Biodiversity Program of the American Museum of Natural History's Center for Biodiversity and Conservation in New York. "We have biodiversity—with genes, species, ecosystems, landscapes, and evolutionary processes—in the city as well as far away. Evolution is, in fact, happening right now in urban biodiversity. Cities also serve as hotspots for regional diversity." The CBO reports, for example, that Cape Town supports

Singapore's streets are famous for their plantings that provide habitat—for example, this butterfly trail, in which over 60 species of butterflies have been observed, on Orchard Road, which is a major shopping street. Photograph: Cheryl Chia, Singapore National Parks Board.

"50 percent of South Africa's critically endangered vegetation types and about 3000 indigenous vascular plant species" and that "more than 50 percent of the flora of Belgium can be found in Brussels, and 50 percent of [the] vertebrates and 65 percent of [the] birds in Poland occur in Warsaw."

Conservation biologist Oscar Pineda-Catalan, who works with both the American Museum of Natural History and the Cold Spring Harbor Laboratory on the Urban Barcode Project (see box 1), agrees: "Urban areas create an artificial perception that cities live isolated [or] independent from nature." Pineda-Catalan stresses that it is biodiversity that provides cities with necessary ecosystem services. "Urban areas depend heavily on natural areas, and their ecological services [are] provided for free, including water and air purification, soil stabilization, noise reduction, heat-island buffers and microclimate regulation, [and] regulation of population dynamics of disease vectors, among others," says Pineda-Catalan.

The assemblages of urban biodiversity, however, often have distinct characteristics. Johnson explains that for urban biodiversity "there is a mixture of established communities, where there is often a combination of native species and recent invading species, and there are novel communities that arise when plants and animals colonize uninhabited places like the bare soil of an empty lot." Pineda-Catalan adds that urban areas generally have "built environments with deep transformations of native ecosystems." Commerce brings species from all over the world to these altered landscapes, and the introduced species could become "invasive species that displace native organisms and transform the urban ecosystems [even more]." For example, in New York City, purple loosestrife, introduced by the nursery trade and from ship ballast, invades wetland areas, decreasing their overall functioning, including as wildlife habitat, and releases of a type of pet turtle, the red-eared slider, are thought to diminish native aquatic biodiversity.

Another frequent feature of urban biodiversity is the presence of synanthropic species, which, Johnson explains, "are the species adapted to environments created or modified by humans. For example, some can use buildings for nesting, and others benefit from food we provide intentionally or unintentionally." Although their dependence on humans varies, starlings, rock pigeons, red-tailed hawks, and peregrine falcons are examples of synanthropic species. Some common urban species, such as gulls, striped skunks, and coyotes, are considered generalists—in contrast to specialists—and are able to adapt to reduced and less-complex habitats. Highly productive, short-lived species also often thrive in cities.

As important as conservation, say others, are efforts to restore the conditions in which diverse species can thrive. Eric Sanderson, a landscape ecologist with the Wildlife Conservation Society, advocates and documents the restoration possibilities

Box 1. The Urban Barcode Project: Students get a taste of scientific discovery.

In the Urban Barcode Project, high school students from New York City's five boroughs explore their city's outdoors and commercial venues to gather biological samples for a thorough scientific investigation that ultimately produces a genetic profile. Jesse Ausubel, acting in a manner similar to his role with the Census of Marine Life and the Encyclopedia of Life, helped with the Alfred P. Sloan Foundation's initiating support of the project. The DNA Learning Center of Cold Spring Harbor Laboratory runs the project, which is now in its second cycle.

"Students run everything," explains Oscar Pineda-Catalan, the Urban Barcode Project manager. "They suggest their projects and develop the experiments and analyses." David Micklos, executive director of the DNA Learning Center, adds that the Urban Barcode project gets New York City students to "go out and look hard at the city they live in," all part of an overarching project that "subsumes much knowledge and intellectual growth." The project also trains and works with teachers. "This is the kind of experiment [that] biology teachers are looking for because it integrates so many key concepts and methods of biology," Micklos says.

New York City teachers and mentors (graduate students, postdoctoral fellows, or university professors) are trained to assist students on Urban Barcode projects. Photograph: The Urban Barcode Project.

The student teams focus their projects within one of five areas: wildlife and public spaces, commercial products and trade in endangered species, food mislabeling, public health and disease vectors, and exotic and invasive species. Once the students define their project and find samples, they participate in a multistep barcoding process, which includes following protocols to extract and amplify DNA, working with a commercial biotechnology company to obtain a nucleotide sequence, using a bioinformatics tool (the DNA Subway, *www.dnasubway.org*) to analyze the DNA, and, finally, checking for any matches in GenBank, the National Institute of Health's database for "all publicly available DNA sequences" (*www.ncbi.nlm.nih.gov/genbank*).

During its first run in the 2011–2012 school year, 75 student teams with 318 students and 35 mentors completed their projects. Among the outcomes, the student investigations spawned 65 new barcodes not previously confirmed by GenBank. These new sequences are being further examined and might eventually indicate that the students sampled and discovered unidentified species.

The students' projects generated other exciting results—for example, validating (or debunking) the authenticity of medicinal and food products and documenting the biological ingredients of museum art materials. One student team conducted the first-ever genetics study of the fungi of Central Park, which, Pineda-Catalan describes, were formerly inventoried according to morphological characteristics. "This is a baseline for further fungi genomic studies in Central Park," says Pineda-Catalan.

Micklos believes that the Urban Barcode Project is a prime illustrative example of a "distributed experiment—a very interesting science educational experience with lots of students involved in lots of places, combining to make a strong contribution to a larger-picture understanding." He says that the project is envisioned for replication in other places.

Pineda-Catalan adds that the project piqued student excitement about how science is done and aroused their curiosity. "Discoveries beget new questions," Pineda-Catalan explains. "That's the way science is done: hypothesis, tested hypothesis, on to new questions. The Urban Barcode Project is an opportunity for students to explore their own ideas, develop the knowledge of science, and make important contributions."

To learn more, visit *www.urbanbarcodeproject.org*.

for New York City. He believes that "in cities, the restoration part of the equation is more important than conservation." Sanderson stresses that restoration should begin with "abiotic elements—looking at water levels, soil types, topography, and light." Once these are restored, "ecosystem parts add up to create a home for biodiversity in the landscape."

Swedish cities: Setting the pace

Many look to Stockholm and Malmo, Sweden, when considering the future of urban biodiversity. New pollution control systems, green roofing,

widespread use of recycled materials and renewable energy, and innovative energy-distribution arrangements are prominent in Swedish cities' sustainable development programs, but urban biodiversity is also a key focus.

Stockholm, with its 14 islands and 160 kilometers of waterfront, is richly biodiverse, supporting over 1000 vascular plant species. In addition, 43 of Sweden's known mammal species breed in Stockholm. With 40 percent of its terrestrial spaces as green spaces and its radial layout and system of connective corridors between city parks and nearby reserves, Stockholm integrates biodiversity into city life. For example, EkoParken, a 27-square-kilometer park partly in Stockholm's center, has over 800 wildflower species and 100 nesting bird species. Found there are Sweden's iconic oak trees, which can last for 1000 years. Their slow decay offers microhabitats for flowers, invertebrates, and birds.

In Malmo, the new Western Harbor district combines sustainable development, transportation, energy, and building plans with green spaces, paths, and waterways that support biodiversity. Malmo biodiversity planning also includes a close examination of soil type and depth of soil for choosing the appropriate type of varied vegetation. The town's well-regarded Green Roofs Research Center further establishes Malmo, together with Stockholm, as a leader in urban biodiversity.

Singapore has over 10 biodiverse ecosystem habitats, including this freshwater swamp and a pristine (unlogged) six-hectare tropical rain forest in the city center's botanical gardens. Photograph: Cai Yixiong, Singapore National Parks Board.

The Garden City: Singapore prioritizes biodiversity

Perhaps no city links its identity to biodiversity as much as Singapore, the tropical Asian city-state that is home to more than 5 million people. In the 1960s, under Lee Kuan Yew, Singapore's first prime minister after independence, Singapore officially designated itself "the Garden City." Biologist Lena Chan, director of Singapore's National Biodiversity Centre of the National Parks Board, explains that "from the beginning, the greening of Singapore [was] an integral part of its development process." This was auspicious for later large-scale biodiversity policy, because, Chan says, "without green infrastructure, you can't have biodiversity conservation."

Singapore has established 22 nature areas, of which four have special legal status as nature reserves. These areas sustain the largest portion of Singapore's biodiversity, which includes an estimated 255 hard coral species, 50 species of intertidal sea anemones, more than 2000 species of native vascular plants, 57 mammal species, 364 bird species, 301 butterfly species, and over 400 spider species.

Assessing Singapore's biodiversity has been a daunting task, and it was not until 1993 that the National Parks Board joined with the private Nature Society of Singapore to begin a biological survey of two of the nature reserves, the Central Catchment Nature Reserve and the Bukit Timah Nature Reserve. "This survey was a real eye-opener because we saw biodiversity we did not know we had, and species we thought were extinct," Chan says.

Currently, Singapore, which is made up of 63 islands, has embarked on a comprehensive marine biodiversity survey with private, nongovernmental, and academic partners. Chan emphasizes that the taxonomic challenge for Singapore is enormous and that Singapore does "not have the taxonomic or ecological expertise, so we would like to collaborate with scientific researchers around the world to learn more about biodiversity." She adds that Singapore has over 10 different ecosystems; is compact, so that all fieldwork is nearby; and that "the National Biodiversity Centre is a one-stop center which issues research permits for biodiversity research."

Singapore is also active in the cities focus of the CBD and worked with its secretariat and the Global Partnership on Local and Sub-national Action for Biodiversity to develop the "Singapore Index on Cities Biodiversity," which, Chan reports, is a model being used by more than 70 cities.

It is all hard work, but Chan feels that "Singapore can share with the world that cities can play their part in biodiversity conservation. You can have biodiversity in urban areas, by balancing development with conservation and doing conservation innovatively." There are also personal rewards. "Saving biodiversity keeps bringing surprises [to] you," says Chan. "For example, here in a very urban area, you can find rare species."

Biodiverse New York City?

New York City might not cross most people's minds when planning an ecotourism weekend. But in fact, its rich natural history can be seen through its green spaces.

When Henry Hudson first made contact with the indigenous Lenape, around what became New York City, the area was a teeming estuary with thick forests, oyster-rich shore areas, and abundant streams and water sources. Sanderson, who wrote *Mannahatta: A Natural History of New York City*, points out that Manhattan once had 55 different ecological communities, such as red-maple hardwood swamps and eutrophic pond communities. According to Sanderson, this has been reduced to "maybe five or six of these communities." He hopes that restoration may eventually create "representatives of all 55 of these ecological communities again. These could be in Manhattan, in the outer boroughs, or if not possible any other way, stewarded outside the city but nearby."

Ellen Pehek, principal research ecologist of the New York City Department of Parks and Recreation, points out that the city "provides habitat for 141 federal or state *endangered*, *threatened*, *special concern*, *rare*, or *SGCN* (*species of greatest conservation need*) animals. This includes 4 species of crustacea, 7 dragonflies, 10 butterflies and moths, 6 molluscs, 30 fish, 3 amphibians, 14 reptiles, 76 birds, and 5 mammals."

Rosenzweig also has a long-standing interest in New York's natural history. In the early 2000s, she and colleagues from UNESCO (the United Nations Educational, Scientific, and Cultural Organization), Hunter College, Columbia University, the New York Botanical Garden, and the Brooklyn Botanic Garden joined together to look at urban ecology. "It was so clear that urban biodiversity needed to be taken on board and nurtured to create a truly sustainable New York metropolitan region. It was a missing element," Rosenzweig says.

Although there is much work to be done, since the early 2000s, the city has put renewed value on nature.

Biologists and geneticists worked together on mitochrondrial, genetic, and morphological evaluations to confirm that this leopard frog, found in Staten Island, is a newly identified species. Photograph: Brian R. Curry.

Parkland has been created or restored; work on wetlands continues; greener buildings are going up; and new venues, such as the restored High Line, a former railway tract converted into a rich garden walkway, generates enthusiasm and educates the public about nature. "People are realizing what it means to live the good life… and doing it right here in New York City," Sanderson reflects. "This is manifest in green markets; fresh local foods; urban farming; green roofs; urban chickens and beehives; daylighting of streams; and interest in where the water, food, shelter, and other things we need come from. This generation is reinventing what it means to live in cites, cities that include, not exclude, an experience of nature."

More people also pay greater attention to the individual species found in New York, and new discoveries still occur, such as the 2012 confirmation of a newly identified species of leopard frog, a group of roughly a dozen frog species that has suffered severe declines in recent years. Jeremy Feinberg, a doctoral candidate in the ecology lab of Joanna Burger at Rutgers, located the frog around Staten Island and worked primarily with geneticist Catherine Newman to confirm it as a distinct species. Feinberg says, "Identifying a previously undocumented vertebrate only several miles from the Statue of Liberty in one of the largest, most well-studied, heavily inventoried urban parts of the Western Hemisphere is exciting and unexpected." New bee species found in the city botanical gardens and a centipede in Central Park are among other recent discoveries. "We still have many questions and species to uncover," says Elizabeth Johnson, "and this biological discovery is just as exciting in urban areas as anywhere else."

Although it was destructive, paradoxically, Hurricane Sandy complemented rather than contradicted this new appreciation of urban biodiversity, adding a compelling argument for maintaining natural ecosystems. "Thinking of Hurricane Sandy, we can see the role of ecologically based adaptation and especially the place of wetlands and marshlands," says Rosenzweig. "We need to continue the work on protecting, enhancing, and reconstructing these wetlands." The New York–New Jersey Harbor and Estuary Program's *The State of the Estuary 2012* report states that 85 percent of the estuary's coastal wetlands present in the 1800s "have been filled or drained,"

Over 150 acres of marsh have been restored in New York City's Jamaica Bay. Here,* Spartina alterniflora *grass, able to withstand both high salinity and regular inundation, is monitored after recent restoration. Photograph: New York City Department of Parks and Recreation.

with the remaining wetlands "degraded to varying degrees." However, wetland losses have significantly slowed, and major restoration projects are underway. Jamaica Bay, for example, is undergoing significant restoration work, including a 2011 partnership effort that installed 8000 eelgrass plantings at the Breezy Point boundary area with the aim to restoring the underwater and sediment-stabilizing eelgrass beds. This year, Rosenzweig's NASA–Goddard Institute for Space Studies Climate Impacts Group will continue studying the New York City wetlands, such as Jamaica Bay, and will report on their possibly mitigating role during Hurricane Sandy.

In addition to the immediate lessons of the storm, there is a continuing need to understand the natural history within urban biodiversity, for both enrichment and planning for the future. "There is a great need to reconnect to our estranged ecosystem that underlies [the] New York metropolitan region, which is an immensely rich coastal estuary," Rosenzweig explains. "Efforts of the past decade have begun to achieve these reconnections. The High Line, the Hudson River parks that now stretch almost the length of Manhattan [that] now [have] plantings with native grasses, and green roofs—these are all examples of the reconnection going on. After Hurricane Sandy, we need to embrace and enhance this ecosystem even more."

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