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Urban Biodiversity Through Sustainable Architecture and Urban Planning

Review Article

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Abstract

Background: In recent years, ecologists, architects, urban planners and decision makers, and citizens have become more aware of the importance of biodiversity in cities, creating a renewed effort to make cities and new developments better suited towards natural habitats. Sustainable architecture and design practices have offered ground to significant discovery and innovation in the art of city-building.

Methods: A literature review of current practices in the Western world of the last twenty years and two case studies will be used to illustrate current efforts and future directions of biodiversity preservation.

Summary: Integrating building strategies and holistic urban ecosystem development, compounded by encouraging interdisciplinary approaches that promote collaborative and bottom-up urban planning through community activism are the main trends in current sustainable city-building.
The literature review is far from exhaustive and requires a historical perspective to better understand implications of past and present sustainability efforts. The paper serves as introduction to a promising field. Relationships between biodiversity preservation and urban planning and design need to be reinforced in order to build a more connected, healthy, and resilient community.

Introduction

Urban Biodiversity and Motivations to Protect it

The environment is changing – as the world undergoes urbanization, human actions have caused dramatic deterioration of the planet's ecosystems. Continued use of natural resources, agricultural development and growing urban form accentuates the destruction of habitats and leads to an increasingly homogeneous distribution of species on Earth. (1) High extinction rates of local species, accentuated by high introduction rates of foreign species, is estimated to be approximately between 1,000 and 10,000 times higher than the natural extinction rate due mostly to land use change, physical modifications of natural landscape, and anthropogenic climate change and pollution. (1) The above phenomena are all examples of important biodiversity loss that in the short term may benefit the livelihood or the economy of certain regions, but in the long term will result in costly trade-offs. (1) Areas whose economy depends heavily on the quality of the natural environment (for example, regions dependent on the industry of tea) are also the most vulnerable to urbanization and habitat changes.

According to conservationists Dearborn and Kark, (2) not only will natural environments benefit from the protection and restoration of biodiversity, anthropocentric benefits also range from the improvement of human health, including reductions in air pollution, emotional wellbeing from contact with nature, incorporation of the intrinsic value of nature in culture, and preservation of ecosystem services provided by the natural environment. (1) However, due to the multiple dimensions of biodiversity, it is difficult to identify the number one indicator with which to quantify these services. In discussions of urban biodiversity and planning, there is a focus on species diversity – the number, type, and relative dominance of different species, as well as ecosystem diversity – the variety of habitats for animal and plant communities. Large variations in patterns of natural diversity are an indicator of loss of ecosystem function. These indicators account for biotic and abiotic factors within ecosystems to provide an idea of the overall health of these complex networks (3) that count on each link of the chain – every species, niche, and habitat – to ensure it functions as healthily as possible.

Methods

Currently, the goal of urban biodiversity conservation is focused on preserving and reconstructing habitats to minimize species loss and encourage human and wildlife coexistence. (14) Therefore, our literature review will be mainly carried out through focuses on parkland creation, minimization of urban fragmentation, and urban canopy development. (17)

Current ecologists and planners only have direct control over two aspects of urban biodiversity: plant diversity and abundance. The ecosystem is complex and chaotic – it has been shown that introduction of non-plant species rarely works due to difficulty for the population to successfully establish and find its place in the local ecosystem. However, when preserving or reconstructing habitat through plant diversity, natural ecological and evolutionary processes are triggered, increasing overall diversity as well. (14)

A key aspect of this habitat reconstruction is a focus on native plants as opposed to exotic or invasive species not native to the local ecosystem. Historically, cities, parks and green areas have been filled with these ornamental exotics or monoculture trees, which do not act as healthy habitat for local native fauna. For example, in Baltimore County, MD, regulations now stipulate that 80% of county plantings must be local flora, with half being native oaks. The habitat of the oak trees attracts diverse fauna, from the communities of caterpillars that feed songbirds to aquatic invertebrates that feed on the oak detritus, and supports healthy fish populations. (6)

For planners, three basic classifications of urban green spaces exist: formal spaces or parks are highly managed green spaces, vernacular spaces are private green spaces (i.e. yards and gardens), while forgotten spaces (Terrains Vagues) are composed of alleys as well as empty and abandoned lots. Each of these three have a naturalized ecosystem function. Formal spaces are highly managed and have frequently low biodiversity, due to the arrested succession and limited renewal functions of these spaces. (5) Vernacular spaces also face these problems; however, these spaces usually have higher species diversity, resulting in a higher biodiversity, albeit a lower number of native plant species. (5) Even though this high species diversity can increase biodiversity, some is still lost due to the lack of habitat for native species. Forgotten spaces, which are frequently less physically appealing, have high levels of biodiversity. In a study of Berlin's forgotten spaces, there were lower numbers of native species found in other more

formal green spaces within the same area. (29) This may be in part due to a naturalization of ecosystem function in these spaces, as they are not regulated to the same degree as more formal spaces, and natural succession can occur. This allows for habitats to develop at a normal and fully functional forgotten spaces, there were lower numbers of native species found in other more formal green spaces within the same area. (29) This may be in part due to a naturalization of ecosystem function in these spaces, as they are not regulated to the same degree as more formal spaces, and natural succession can occur. This allows for habitats to develop at a normal and fully functional rate. Using these forgotten spaces as examples, we may be able to create urban spaces that mimic natural levels of biodiversity within urban spaces, and perhaps, even create ecosystems with specific dynamics that reflect the unique nature of urban spaces. (28)

Although a green space may be filled with diverse and native flora, an issue arises in the integrity of the landscape due to the heavy fragmentation found in urban environments. This urban environment is known as a "mosaic of patches" (14) with minimal connections, migration routes, and exchanges. Ecologists have analyzed this phenomenon using Island Biogeography Theory, modeling each patch or fragment as an 'ecological island', susceptible to edge effects, small populations, invasive species, and widespread disease. Creating parkland and natural space with native plants is insufficient if they are to be isolated and surrounded by asphalt. This brings rise to the practice of creating green corridors, connecting these habitat spaces with green areas throughout the city. These can take the form of linear parks, restoring habitats along a river or stream, natural greening in the middle of a boulevard, or wildlife crossings that allow animals to safely cross human-made barriers.

There are limitations on the success of green corridors. They are heavily susceptible to ecological edge effects, can act as disease vectors, and are not suitable for every species. Another limitation is the number of corridors needed for a successful, resilient ecological system. Rudd (26) found, by quantitatively analyzing connectivity and ecological metrics, that the best network was found by having over 300 discrete corridor connections based on the parkland and habitat spaces in the urban area of Greater Vancouver. Clearly, from a planning perspective, this is an unreasonable amount, interfering with the built environment and daily happenings of a large city. The solution here is to consider green corridors as integrated into the city itself –roads, boulevards, backyards, alleys, and right of ways being areas for people, native flora and fauna, and paths for ecological connectivity. (26)

It is abundantly clear, that even if a native habitat is reconstructed or preserved in an urban zone with all integrity and connectivity issues thought of, an urban habitat resembling a natural one in form does not mean they entirely resemble each other in function. (14) Hostetler (16) notes that although there is a current heavy focus on 'green infrastructure' of protected space and corridors, the design of surrounding developed areas is overlooked. These surrounding areas have a heavy influence on the protected areas through obvious issues (such as connectivity discussed above), and less obvious but heavily influencing factors such as runoff and temperature regulation, altering the function of the habitat's ecosystem. For example, a heavy rain event over a hardened, developed area results in heavy runoff (since developed areas do not hold much water in their surfaces) into parkland, bringing with it pollutants and particulates not expected to be found in a natural area. To have truly green infrastructure, a more integrated approach to planning habitat and the surrounding areas must be taken, considering the entire city as a habitat for native flora and fauna rather than just protected or reconstructed areas.

As easy as it is to say that we should take a more holistic approach, there is a major barrier to implementing this approach in our cities with current practices: there exists a sharp divide between planners, political decision-makers, and natural scientists. Each group works is in its own 'silo', with minimal knowledge sharing and collaboration. In a 2006 study of Swedish planners, Sandström (23) found that biodiversity was an important consideration to most planners, but self-evaluation showed a distinct lack of knowledge and resources to carry it out appropriately. To achieve the planning of a holistically biodiverse and healthy landscape in our urban zones, there must be more collaboration between these groups than currently stands.

Results

As discussed above, current practices include the creation of formal green spaces within urban areas and the connection of these formal spaces via linkages and corridors. However, this may not be enough. As cities become increasingly dense, vernacular green space decreases. (5) This has led to a limitation of habitat provision and, therefore, biodiversity. (5) To create successful habitats that encourage natural growth, succession, and rich biodiversity, we must consider using the built form, at the local and individual level, to increase spaces for habitat in addition to urban agriculture and green space designed for human use by creating habitats within mixed used development complexes.

Methods for increasing urban biodiversity include adaptive design which builds natural habitat into the urban form in ways such as green roofs, terrace garden infrastructure, and green walls or other vegetative vertical structures. (6) These methods for increasing urban green space have been shown to also increase habitat and overall biodiversity in cities. Catalano et al. (27) show that by replicating specific habitats within green roofs and allowing these green roofs to complete natural cycles of growth, death, and rebirth (which ultimately result in natural succession), these immensely rich and biodiverse communities can compensate for the demolition of green spaces due to urban growth. These green roofs should attempt to use as many native species as possible to promote habitat for local populations of insects and animals as well as to allow for aesthetic change over time. (27) The goal is to maintain these green roof installations with as little human interference as possible to allow a natural progression of habitat formation.

Another important structure for increasing biodiversity is vegetative vertical structures, which seem to be crucial in the identification and the protection of biodiverse and vulnerable avian habitats. In one of the first studies on the matter by Culbert et al., (13) vertical structures such as densely covered tall trees, green walls and vertical gardens complement horizontal structures to enhance avian biodiversity. Vertical structures, especially in cases where they are combined with horizontal structures (such as rooftop gardens) can be extremely useful in increasing both bird and insect biodiversity in urban settings that are near forested areas or near migratory routes. Benefits like the mitigation of air pollutants, noise reduction, lessening of the urban heat island effect, increases in walkability and real estate value, and reduction of stress due to its aesthetic advantages are recognizable. The best example is the proliferation of high-end, high-rise apartment buildings around the world that integrate rooftop gardens and vertical forests (for example, one in Porta Nuova, Milan is home to 730 trees, 5,000 bushes and 11,000 covered balconies). These provide inhabitants with an improved microclimate while also contributing to the implementation of urban agriculture, increases in urban density, and the limiting urban sprawl. (22)

Looking ahead, popularization of methods for incorporating different green spaces into residential developments can significantly enhance the urban ecosystem, creating greater biodiversity within the city and, therefore, creating biophysical communities that are more resilient and significantly healthier. From a sociopolitical perspective, optimistic changes are slowly taking place: as the United Nations declared 2011-2020 to be the Decade on Biodiversity, both governments and citizens are engaging in the dialogue (such as UKGNC Task Group of Association of Local Government Ecologists, UN Major Group of Children and Youth who assisted in drafting the New Urban Agenda). Certifications like LEED (Leadership in Energy & Environmental Design), regulations like municipal bird-friendly guidelines and tools like the Biotope Area Factor (proportion of area that is dedicated to be green spaces in a city's inner area), potential vegetation maps (19) in urban areas, and Singapore's City Biodiversity Index (24) are becoming better known. Their usage strongly encourages future cooperation between different actors in the development of a more holistic approach to the question of urban biodiversity conservation.

Discussion

To further discuss and illustrate practices mentioned above, two distinct case studies will now be presented. The first one speaks more to the physical design and planning perspective and is about how Malmö integrated biodiversity in a holistic manner, blurring the boundaries between nature and city, and questioning the very relative definition of nature itself. The second case study pertains more to the question of balance that must be found between social, local economic, and biophysical research of sustainability. As an initiative powered by local citizens' active involvement, the Bronx River project highlights a successful case of bottom-up urban planning model that should be widely reproduced in the future.

Case Study: Bo01 Malmö, Sweden (Waterfront Brownfield Redevelopment Plan)

Bo01 (named for the year of its inauguration (2001), and the Swedish verb 'Bo' meaning 'to dwell') was built on a former industrial port in the Western harbour of Malmo, Sweden. The land that was revitalized suffered from extreme soil pollution. It is currently supplied by 100% renewable energy and serves as an example of sustainable urban renewal. Across over 54 acres of land, Bo01 offers housing to 2343 people with a density of 26 residential units per gross acre, or 43 people per acre. (4) This density is balanced by the 50% open space dedication on the site. (4) Despite the density of urban fabric that makes up Bo01, it has high levels of diverse green space and urban biodiversity. Trees, creeper plants, ponds and green roofs and walls make up a highly-connected network of green spaces which house at least fifty varieties of plants, and offers food and habitat to a variety of seabirds and other fauna. (4)

According to Austin, (4) the greatest gains in biodiversity could be found in the built form, as opposed to naturalized areas. By putting emphasis on building space that was useable as habitat for a variety of species, Bo01 brings aspects of the biophysical environment into residential developments. This was done by maintaining sufficiently high levels of permeable ground, green space, and integrating hydrological features into the development site. (4) Bo01 increased biodiversity through exceptional urban ecosystem development, including built habitats such as bat boxes, bird houses, and hydrological features which run through the entirety of the site, increasing connectivity at a micro scale. (4) Nine species of seabirds breed at Bo01, salamanders, frogs and three species of bat are residents in the courtyards. The incorporation of green roofs into the site helps with storm water management, which minimizes erosion of ecologically sensitive riparian zones, and provides breeding grounds for seabirds. (4) The saltwater canal, which was incorporated as a water management tool, is proving to be a valuable habitat for species of fish, shellfish, and crustaceans. (4)

In addition to the biophysical environment provided within Bo01 it was acknowledged that any development of this density would displace some wildlife and, therefore, there were offsetting activities performed to compensate for potential habitat loss in other parts of the Western harbor. Kruuse, Bo01's main ecologist and their team established a design that created conditions favorable to species that are tolerant of human activity, intelligently recognizing that certain species in the area are better at coping with human settlement conditions, which resulted in a robust urban ecosystem. (4) Bo01 also incorporated a transferable points system for any future development projects to integrate biodiversity and green infrastructure at an early stage of their development that awarded points for a variety of biodiversity implementations, including the use of native herbs and shrubs for ornamental plantings, the creation of urban agricultural spaces, and reserving spaces for natural succession within the open spaces of the development – an immensely important factor in increasing biodiversity and creating robust and healthy urban ecosystems. (4)

What makes Bo01 such a remarkable case is the successful use of integrated built form and habitat and the cooperation between government and private sector actors that was vital to its success. Architects, planners, and ecologists worked side by side to create a space that was beautiful, sustainable, and ecologically sound.

Case Study: Bronx River, Bronx NY

The Bronx River is a 39km freshwater river rising in the Catskill MounThe Bronx River is a 39km freshwater river rising in the Catskill Mountains north of New York City, and flowing into the saltwater tidal estuary of the East River at Hunt's Point in The Bronx. As the only freshwater river in New York City, the Bronx serves important social, ecological, and ecosystem services roles. It is an important transportation corridor between the suburbs of Westchester County and Manhattan, and is a recreational center in the borough of The Bronx, with parks, gardens, and multi-use pathways along the shore. The mouth of the river is characterized by heavy industrial development, with most of the watershed being covered in impervious surfaces. However, the river still supports wildlife from invertebrates to small mammals and diverse vegetation. The Bronx River is an important tributary to the East River and Long Island Sound estuaries, and provides numerous ecosystem services to New Yorkers including storage and transportation of freshwater as well as storm water drainage.

Industrialization and human interference in the river reaches back to the mid 19th century, starting with the construction of the New York Central Railroad in the valley and by the 1880s it was known as an "open sewer". Into the 20th century, efforts began to restore and reclaim the river – beginning with the creation of the Bronx Park and the Bronx River Parkway, which today is a major commuting corridor surrounded by a narrow ribbon of vegetation. However, unfortunately, the vegetation and riparian areas in these 'preserved' areas are of poor quality and have been degraded by heavy urban development around them. During the Robert Moses era (around 1930s to 1960s), these efforts came to a halt as numerous highways were built across the valley, destroying the river, urging industrial development, and lowering connectivity and quality of life in the low income South Bronx area. In the late 20th century, community groups came together to pour life back into the community and ecosystem: volunteers with the Bronx River Restoration Project began with a focus on debris clean up and started a legacy of community stewardship and activism in the Bronx River Valley, particularly in the neighborhoods of the South Bronx.

Today, ecological restoration and biodiversity improvement in The Bronx are still focused on and led by the community. Founded in 2001, the Bronx River Alliance is a partnership between over 40 organizations from the community, business, the public sector, and the municipal government. Following community feedback and coordinating with stakeholders, the Alliance encourages and promotes ecological restoration of the Bronx River using quantifiable goals and indicators from the ecosystem itself. Physical indicators, such as water quality and channel stability, added to biological ones, such as abundance of macroinvertebrates and migratory birds in the valley, contribute to a scientific understanding of the current state of the river and what needs to be accomplished to improve ecosystem services and quality of life in the South Bronx. (8)

Working with the NYC Department of Parks, the Alliance's efforts are currently focused on habitat restoration, regulation, and policy creation, as well as runoff and storm water controls in the entire watershed. Retrofits in the urban area include plantings of water retaining natural vegetation, 'greenstreets', and green roofs to reduce the amount of raw runoff entering the water system. (8)

Perhaps the most important aspect of the Bronx River Alliance, as well as numerous community organizations doing similar sustainability work in the area, is the role of outreach. Community organizations work together to gather input from members and stakeholders on restoration work – this is a project for and by the community. Sustainability organizations have also had a focus on involving youth volunteers from surrounding neighborhoods and schools, giving them exposure to sustainable living practices, science education, and a strong sense of place and pride in their community. Initiatives such as these foster a sense of nature as an integral part of the urban ecosystem, promoting better understanding and stewardship of natural resources in the future generation. (18)

The Bronx River is in a much better state today than was found in the mid 20th century, acting as a neighborhood center for recreation, education, and active transportation, while continuously improving to be a quality

habitat for a host of diverse native flora and fauna performing crucial ecosystem services for the surrounding communities. In 2007, as "a testament to an increasingly healthy Bronx River", a beaver was spotted living in the river and building a lodge: the first beaver seen in New York City in over 200 years. (21)

Conclusion

The practice of preserving and improving biodiversity within urban regions which aggregate an increasing number of humans must exist within a greater framework of sustainability. The impacts of the urban ecosystem extend well beyond the limits of an individual city as well as beyond the realm of ecology. Urban biodiversity shapes the economics, health, and social and cultural heritage of our communities, which in turn shape the biodiversity of our urban spaces. Current practices in urban biodiversity focus too heavily on the separation of human and natural environments. While preserving formal green space is important to the work of urban ecology, incorporating adaptive design and natural habitats directly into the built form will result in higher levels of biodiversity, a healthier urban ecosystem as well as a healthier, more livable human environment. By working within a holistic framework which values all life and all habitats equally, planners, architects and ecologists can work together to create communities that are biodiverse, and, in turn, sustainable.

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