BIODIVERCITY AND REGION: A UNITARY SYSTEM
THE PARADIGM SHIFT IN 21ST CENTURY URBAN DEVELOPMENT

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INTRODUCTION

The conception of the regional urban system and urban development management requires a fundamental paradigm shift in the 21st century. In the last hundred years, society has undergone profound changes in its ways of life and the way it relates to the natural environment and biodiversity. In addition, the high complexity of urban systems has rendered obsolete the paradigms, concepts, and knowledge that have described and explained them. Therefore, today, urban development trajectories and spatiotemporal behavior and what they mean for people's well-being cannot be justified under past paradigms, especially those that understand the city as a system isolated from its environment, autonomous, and governed by its own laws.

In the emblematic book Cities in Evolution, Patrick Geddes, a founder of urban planning, said at the beginning of the 20th century that "it takes a region to make a city." Geddes was the first to draw attention to two aspects. The first aspect is that time is a fundamental component of the structure of cities; therefore, cities evolve not only in space but also in time and even "conurbate." This term describes how cities extend and merge spatially over time. The second aspect is to consider the region as the primary socio-ecological system encompassing the urban system as a whole and a fundamental component of the urban structure: region and city are a unitary system.

On the contrary, the reductionist and objectified vision of urban planning and urbanism of the 20th century sees and understands the city as an object isolated from the regional environment deprived of ecology. This view is still valid, for example, in Professor Michael Batty's book "*The New Urban Science*," which addresses fundamental urban research topics, such as transportation, land use, and population, among others. Batty's urban characterization is sophisticated and quantitative, making it an outstanding contribution to urban scientific knowledge. However, there is not a single reference to the ecology of urban systems. It seems as if the urban phenomenon emerged on a blank canvas, an empty landscape without ecology and biodiversity in which the city appears and develops following its own socially determined laws.

The disciplines traditionally dedicated to studying and analyzing cities, which today continue to determine urban development management, persist in omitting the ecology that governs, defines, explains, and makes every city possible. This omission will prevent progress toward ecologically sensitive development that considers biodiversity a fundamental component of integrated urban development.

THE CITY-NATURE DICHOTOMY: A PARADIGM THAT FOSTERS ECOLOGICAL DEGRADATION

The city concept has been historically dichotomous, opposed to the natural, and separated from nature by foundational acts. Such as those implemented by the Greeks and Romans, who drew a clear line dividing the dominated world -that is, the sphere of the civilized and the scope of human rationality- from the rest -that is, the wild and untamed world and the uncertainty of a threatening, intimidating, unknown and aggressive nature. The urban environment then constituted a place of certainty in which solid walls excluded natural forces and the surrounding biodiversity.

Thus, for example, within the medieval mythology associated with forests and wetlands, ominous signs - such as witches, spells, curses, and diseases - always appear; that is, the evils attributed to those natural environments that medieval civilization had systematically destroyed. This destruction process inherited from a threatening conception of nature still continues, although the reasons are more pragmatic and economic today. The change we have observed in the environmental awareness of Western civilization has not yet reached urban development. In the vast majority of the world's cities, the latter is still anchored in obsolete concepts - essentially aesthetic, pragmatic, and economic - that do not make room for new paradigms that truly incorporate ecological processes and biodiversity as supports for the well-being of their local populations.

BIODIVERCITY AND REGION AS ONE UNIFIED SYSTEM

Everything materially necessary for a city to function -including water, food, and the materials needed for infrastructure- comes from outside the urban limits, in many cases from distant latitudes. From a metabolic point of view, which considers the inflows and outflows of matter and energy, the city and the region form a unitary and indivisible system (Kennedy et al., 2007; Baccini and Brunner, 2012). That is, without a region, there is no city.

Until the industrial revolution, most of the inputs that supported urban life came from surrounding areas. Land use location models, such as Von Thünen's, considered the city as the center of a system of concentric rings in which agricultural, forestry, and other activities were located following an order that obeyed the commercial valuation of their respective products. Thus, the production of the most expensive goods was found in the rings closest to the urban center, reducing transportation costs to deal with the higher land costs of such locations.

Likewise, archaeological evidence shows that proto-urban systems

-such as Ur, Babylon, or Çatalhöyük- were surrounded by agricultural areas that supplied food and construction materials. In other words, the trade of goods from distant places was a luxury and was concentrated on small items of very high value. Thus, the region explained the phenomenology of each city (Mumford, 1956; Bairoch, 1988).

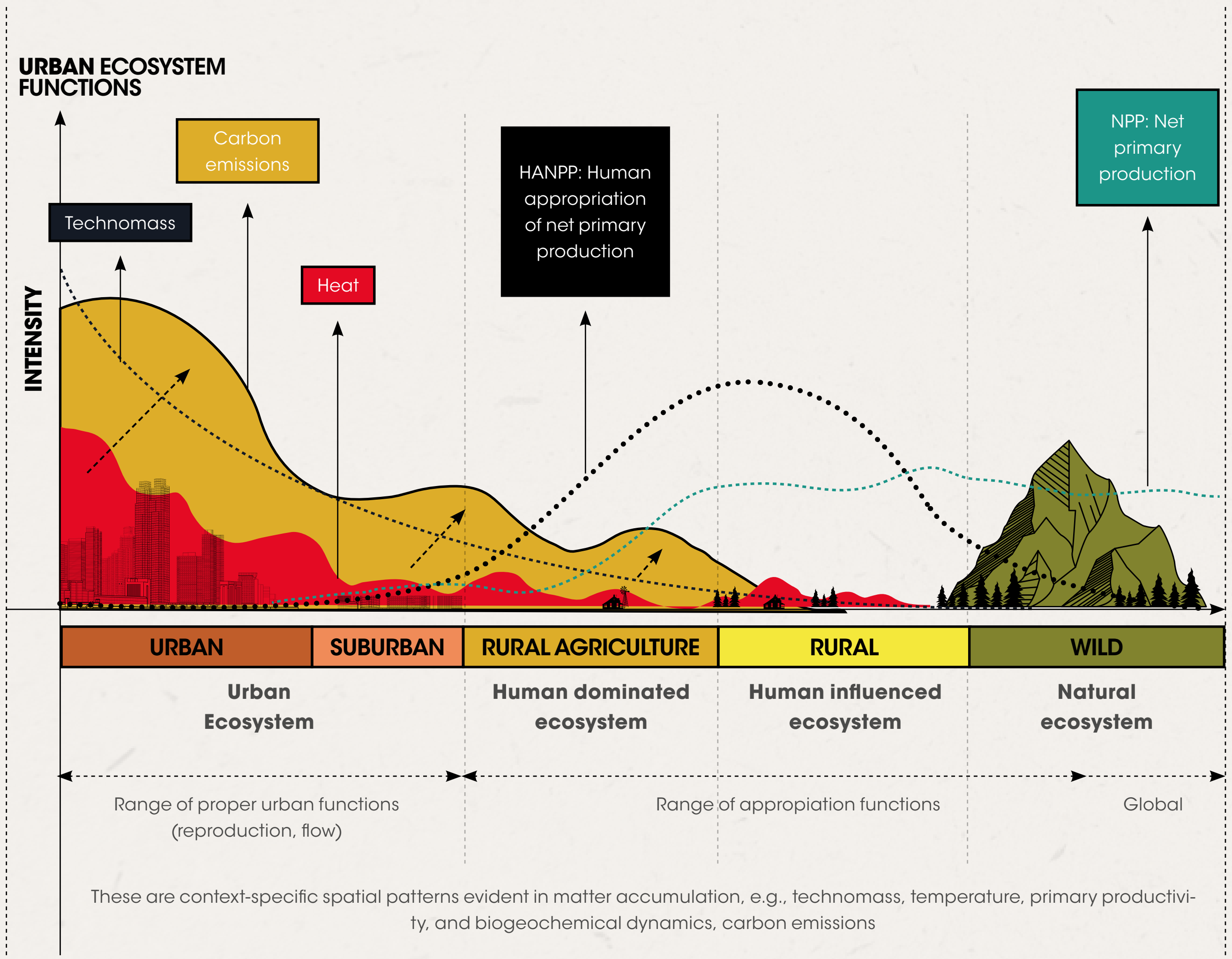
From the point of view of biodiversity, the unitary system has been maintained despite industrialization. City-biodiversity relationships have become more complex but are still strongly determined by spatial interactions at local and regional scales. These interactions are visible in patterns of change in ecosystem functions and metabolic behavior across the urban-regional system. In particular, processes such as accumulation of matter - e.g., technomass, a concept that points to all matter that has been transformed by human labor per unit area and time - biophysical dynamics - e.g., temperature and primary productivity - and biogeochemical dynamics - e.g., carbon emissions and primary productivity - are determining local ecological processes but generating context-specific spatial patterns at the regional level (Figure 1).

Urban development that promotes BiodiverCities must necessarily incorporate regional and peri-urban ecosystems into its spatial structure while recognizing and respecting their ecosystem functions. This makes it possible to maintain and increase the flow of ecosystem services that these ecosystems provide to local populations.

FUNDAMENTAL BIOPHYSICAL INTERACTIONS, CITY-REGION

The primary resource that every city consumes is air, followed by water. Both materials come from outside the urban boundaries to be processed physicochemically through a series

Figure 1. Patterns of change in ecosystem functions and metabolic behavior across the urban-regional system.
Source: Prepared by the author.



of complex transformations related to specific urban functions. Generally, when air and water leave the urban limits, they present lower levels of quality due to the presence of pollutants, unwanted nutrients, and other elements that, if not adequately treated, can affect regional ecosystems. It is widely recognized in urban science and practice that the urban benefits enjoyed by city dwellers ultimately have adverse effects on air and water that extend beyond urban boundaries.

Another product of urban metabolism that affects the urban-regional system is heat. Heat comes from both the structure and functioning of the city. The thermal patterns present in cities are complex and exceptionally heterogeneous, even though they obey regularities present in the vast majority of the world's cities (Lemoine Rodríguez et al., 2022). A clear example of this is the concept of urban heat islands, which indicates that the temperature inside any city will be between 2 and 6 degrees higher than the temperature of the surrounding region (Oke et al., 2017). Thus, the greatest challenge of the hotter urban climate is related to climate change, which will increase exposure to heat waves and affect the well-being of urban populations. This urban heat will also directly affect ecosystems and biodiversity, both within cities and in the urban-regional context (Figure 2).

BIODIVERCITY AND ECOLOGICAL PROCESSES

Ecology characterizes ecosystems through four fundamental ecological processes. First is the water cycle, which moves or accumulates in soil - in rivers or lakes - or the air - in air humidity and evapotranspiration from vegetation. Then comes the material cycle, which includes fundamental elements such as carbon and oxygen in addition to nutrients such as phosphorus and nitrogen. Third, comes the energy cycle, which is fundamentally captured by vegetation -primary producers- and introduced into the food webs of any ecosystem -the food chain. And last is ecological succession, which is the change in the composition and structure of the species present in an ecosystem over time.

For urban ecology, urban systems are the particular habitat of human beings that, to materialize, require the transformation of the earth's surface, which leads to a series of fundamental changes in the four ecological processes underlying all ecosystems. For example, the alteration resulting from the sealing of the soil by pavements and built structures adds many new materials coming from distant places, sometimes thousands of kilometers away (Inostroza and Zepp, 2021). These materials have different bio-geochemical behaviors and allochthonous elements that can eventually alter the health of ecosystems, such as heavy metals introduced by the wear of infrastructure in environments free of them that threaten local populations of fragile species, such as amphibians.

On the other hand, a city has between 2,500 and 9,000 tons of accumulated anthropogenic materials on average. This volume increases to close to 70,000 tons in city centers such as Bogotá, reaching 500,000 tons in New York. This enormous body of material in urban systems is constantly growing and constitutes one of the most significant challenges for BiodiverCities. Why?

When observing the material behavior of ecosystems like forests and corals, there is a rule in terms of the ecosystem's physical structure growth: the total sum of the biomass of the primary producers, such as plants and trees. Growth stops when the ecosystem reaches its climax. At this point, material productivity - the amount of biomass an ecosystem produces per unit of time - and respiration stop increasing and the physical structure of the ecosystem stabilizes. The stabilization of productivity and respiration allows the size of the ecosystem to remain stable over time. This closed material cycle is an ecological behavior that ensures ecosystems' long-term health and resilience and from which urban systems must learn.

ECOLOGICAL PROCESSES IN A BIODIVERCITY

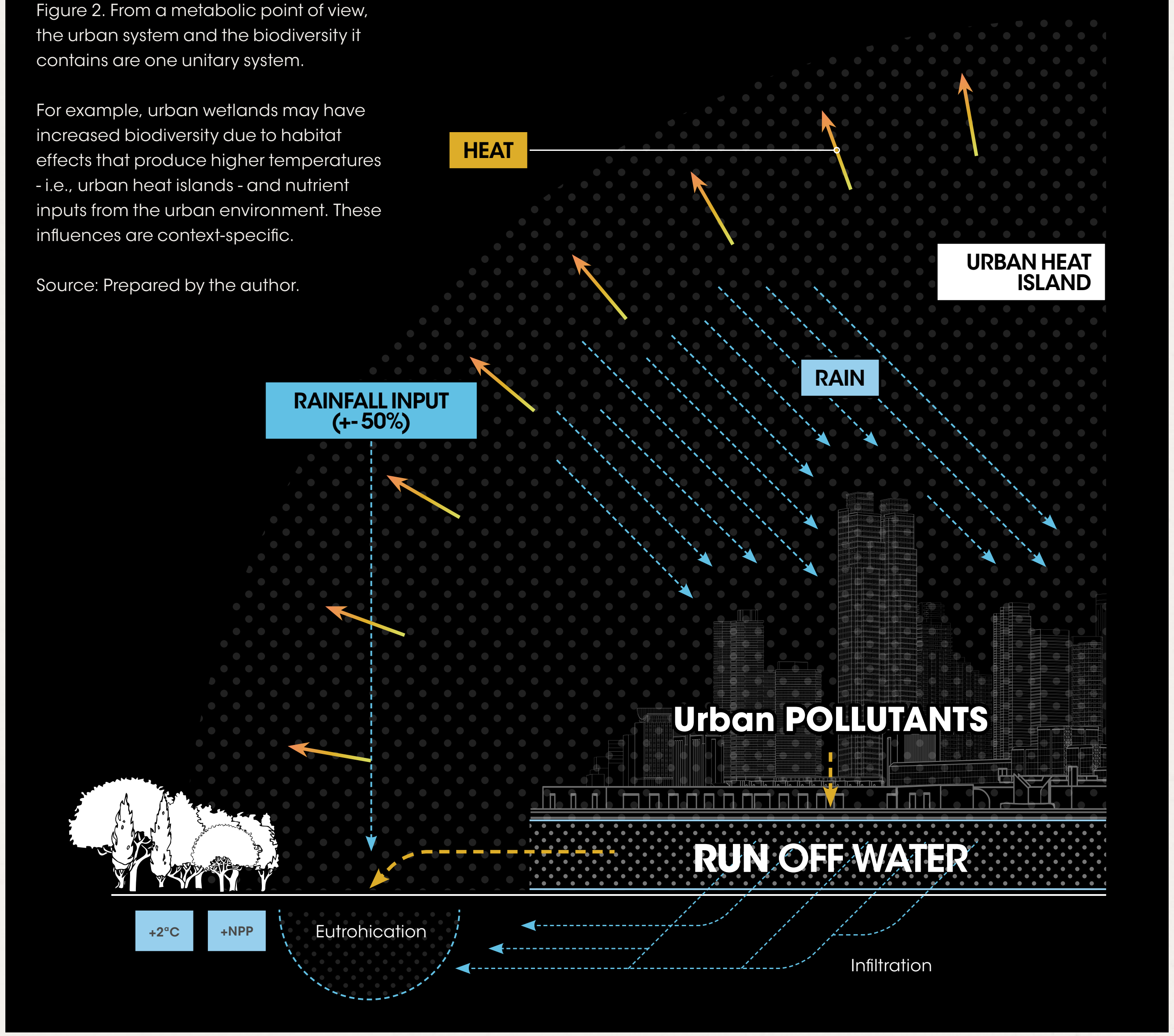
A city seeking to move towards a BiodiverCity should promote the maintenance and recovery of ecosystems such as soil, urban forests, wetlands, rivers, green areas, and green infrastructure in general. These ecosystems contribute to the sustainability of urban life through the provision of ecosystem services, such as rainwater infiltration and flood risk reduction, local climate regulation and control, recreation, and particulate matter absorption, among others (Costanza et al., 2017). Without such ecosystem services, urban life would not be possible.

That is why these ecosystems need to be managed with ecological criteria. A BiodiverCity must pay special attention that the management of the four fundamental ecological processes of any ecosystem ensures ecosystem resilience. Including first, a water cycle that maintains the air and soil moisture levels and ecological flow required by wet ecosystems; second, a material cycle that ensures that critical nutrients, such as nitrogen and phosphorus, are at adequate levels for the entire food web. Third, a cycle of energy from the sun that is adequately distributed at each trophic level; and fourth, a process of ecological succession as a mechanism that determines a species composition of urban ecosystems that is ecologically tuned with the species composition at the regional scale.

Figure 2. From a metabolic point of view, the urban system and the biodiversity it contains are one unitary system.

For example, urban wetlands may have increased biodiversity due to habitat effects that produce higher temperatures - i.e., urban heat islands - and nutrient inputs from the urban environment. These influences are context-specific.

Source: Prepared by the author.



BIODIVERSITY ISLANDS AND BASINS

Spatial interactions between a region's biodiversity and urban systems are complex and depend on each species and taxonomic group. It is usual that different organisms require different environments for reproduction and survival and possess differential displacement capacities. Thus, the interior of urban areas can offer vital habitat and nutritional possibilities for those species flexible enough to cope with the pressures and stresses of the urban environment. In addition, the reduced presence of predators creates favorable conditions for colonization by opportunistic species. In general, within urban systems, green areas, urban parks, rivers, wetlands, and coastal edges are places that diverse living organisms use, either as islands or as ecological connectors, allowing them to move within urban areas or the regional environmental system.

Islands are highly biodiverse urban spaces not ecologically well connected to the more extensive regional system. These islands are not well integrated with the flows of biodiversity that move and interact at the regional scale. In the latter, each species has differential ranges of movement that can be greater or lesser depending on their motor skills or the degree of fragmentation of the landscape. On the other hand, elements, such as river basins and coastal edges, generally operate as connectors integrating the biodiversity found in the cities with that present in the larger regional ecosystem due to their linear-directional condition.

In the urban-regional context, biodiversity-city interactions can be understood through the concept of basins. A biodiversity basin is the area of movement and habitat larger than the urban area where species exist. A biodiversity basin is always specific and will vary in size, shape and spatial extent depending on the size, mobility, reproductive, and feeding habits of the species in question[1]. Thus, a BiodiverCity should promote an intra-extra-urban system of biodiversity basins that allow the movement, interaction, and reproduction of as many local species as possible.

LESS IS MORE: TRANSFORMATIVE CHANGE IN THE CONTEXT OF URBAN-REGIONAL DEVELOPMENT AND MANAGEMENT

Transforming urban-regional systems into BiodiverCities requires a transformative change in the paradigm of urban development and management. Adequate management of the four ecological processes of any ecosystem must consider the urban-regional system as a large ecosystem and not concentrate on arbitrary administrative limits defined as boundaries. To incorporate truly ecological considerations, it is also necessary to transform the merely aesthetic and cosmetic conviction that predominates in urban planning and design and that only understands its social and economic implications. The ecology of the city, in the city, and for the city (Wu, 2014) is an essential scientific foundation that can provide rationale and empirical evidence to enable urban planning to achieve a BiodiverCity's goals.

Likewise, a change in the paradigm that governs how green infrastructures are managed and handled within cities is required. Today, aspects such as species composition and biomass management are mainly based on aesthetic criteria. While large lawns are periodically mowed, and fallen leaves are constantly removed, any symptoms of colonization by other local species are immediately controlled, even with nineteenth-century pruning practices. This is ecologically blind management that neutralizes the colonization processes of local species and the formation of specific ecosystem communities that may change in their taxonomic composition due to ecological succession.

Current practices do not allow urban green areas to become ecologically attuned to regional biodiversity or to become nodes in a more extensive ecological network.

To change this trend and prevent its effects, instead of doing more, we must do less. We must let nature and its processes reconquer the spaces that we can free of pavements and infrastructures so that local species can arrive and compete following their own dynamics. We must abandon the unhealthy attitude of aesthetic maintenance of green areas and parks in which the grass is periodically cut and all the biomass extracted. This prevents the ecological succession essential to maintain ecosystem services -as vital as pollination- that possess spatial dynamics of regional scope.

A green infrastructure with less human intervention is potentially healthier and, therefore, will be in a position to provide more benefits than only aesthetics. A wilder nature free from human control is the aesthetic and ecological paradigm of a BiodiverCity that coexists with the fundamental processes of its ecosystems in tune with regional-scale environmental cycles.

CONTEMPORARY URBAN DESIGN, ECOLOGY, OR COSMETICS?

Over the last few decades, several urban projects have appeared claiming ecological principles. In many cases, such principles have been treated superficially without proper environmental assessment tools constructed using the scientific method. Therefore therefore, such projects have not been able to deliver the promised benefits. An example of this merely cosmetic ecological management is the Houtan Park in Shanghai, China, which intended to clean up more than 600,000 gallons of polluted water from the Huangpu River and increase plant and animal biodiversity. The author visited the park in 2016, and it is closed with no public access allowed. During that visit, the deterioration of vegetation and fish deaths were observed.

URBAN DEVELOPMENT, ECOLOGICAL DETERIORATION, AND URBAN-REGIONAL PLANNING: THE CASE OF LATIN AMERICA

Although urbanization trajectories faced by Latin American cities are heterogeneous, diverse, and complex -as are their ecosystems from Mexico to Patagonia- it is possible to identify four particular characteristics of their urbanization processes.

1. **Rapid urban expansion.** Urban expansion processes are brisk and with high land consumption rates -which can reach 20 m² per minute- and take place in the absence of comprehensive urban planning that respects or enhances ecosystems and their benefits (Inostroza et al., 2013).
2. **Size and urban structure.** Capital cities in Latin America have a high primacy over the respective configuration of the urban system, as capital cities concentrate most of the population within a relatively demographically weak remaining urban system (UN Habitat, 2012). This primacy affects biodiversity in densely urbanized territories, their regional ecological connectivity, and, therefore, the flows of ecosystem services generated from it.
3. **Informal urban development.** A large part of urban development in Latin America is informal (Inostroza 2016, 2017; Inostroza and Tábbita, 2016) and is markedly located in vulnerable areas that constitute relevant, fragile, and highly biodiverse urban ecosystems. Informal urban development in Latin American cities is a problem of inequality that encompasses social and gender asymmetries in access to urban land. In turn, it is affecting the most fragile ecosystems.
4. **High biodiversity under threat.** The biodiversity present in urban and peri-urban ecosystems is high and relevant. It is strongly threatened by the lack of adequate intra-extra urban ecological connectivity, which adds to the increased fragmentation of urban ecosystems in Latin America and is a fundamental challenge for sustainable urban management (Inostroza et al., 2013). In spatial terms, biodiversity also responds to a center-periphery pattern.

As a result of these trends, forests and peri-urban wetlands in Latin America are permanently threatened by urban development that views them as available land and does not incorporate the benefits they provide to local populations into their valuation structure. An example of this is Chile's urban and peri-urban wetlands, which have suffered systematic fragmentation and habitat reduction (Rojas et al., 2015; Arriagada et al., 2019; Muñoz Lobos et al., 2020). This is the case of the Tres Puentes urban wetland in Punta Arenas, which provides habitat for more than 70 nesting birds -including the endangered Ruddy-headed goose, a species in danger of extinction- concentrated in 65 hectares. This wetland is threatened by the urbanization process promoted by the State with the construction of road infrastructures that induce fragmentation, habitat reduction, and, consequently, loss of biodiversity (Kusch et al., 2008; Inostroza, 2009).

The need to modernize regulatory frameworks with 21st-century ecological criteria that allow better management of urban-regional ecosystems is a pending task in much of the world. In Europe and China, significant efforts are being made to improve the institutional framework for urban-regional planning by including concepts such as ecosystem services (Zepp and Inostroza, 2021; Zepp et al., 2021). In Latin America, it is evident that planning and land use systems are generally weak in their ecological components. They are challenged by the scarcity of resources for investment in environmental infrastructure and the lack of qualified human resources for analyzing and managing urban-regional environmental relationships. There is a high sectarianism degree in Latin American territorial planning systems with fragmented competencies in a range of authorities and institutions that often have complex and atomized governance traditions. This generates significant uncertainties regarding the positive and negative ecological impacts of new urban developments, their effect on regional ecosystems, and the delivery of ecosystem services.

Urban planning and management in Latin America are examples of the global need to implement specific urban development policies that address their impacts on urban ecosystems' ecological structure and consider the populations' vulnerability in their vicinity (Inostroza, 2017). It is also necessary to advance in the materialization of urban-regional ecological connectivities that, although they may be considered in existing planning instruments, in many cases have not been implemented (Vasquez et al., 2016).

KEY MESSAGES

→ **City, an obsolete concept.** A change is needed in the approach to the city as a system isolated from its environment, autonomous, and governed by its own laws. The current paradigm omits the ecology that governs, determines, explains, and makes every city possible, as well as the scale (regional and global) on which it operates.

→ **Without a region, there is no city.** Everything materially necessary for a city to function comes from outside the urban limits. This implies the maintenance and recovery of urban forests, wetlands, rivers, green areas, and infrastructure in general at a regional scale. Without such ecosystems and their ecosystem services, urban life would not be possible.

→ **Four processes that every BiodiverCity must maintain.** The development of BiodiverCities should be focused on maintaining four fundamental ecological processes to increase their resilience to global environmental change: i) water cycle, ii) material cycle, iii) energy cycle, and iv) ecological succession processes. One way to achieve this is by implementing nature-based solutions that enable ecological connectivity of the urban-regional system as a whole, going beyond the emphasis on strictly intra-urban connectivity.

→ **How could BiodiverCities be characterized?** In the urban-regional context, biodiversity-city interactions can be understood through the concept of basins. A biodiversity basin is the area of movement and habitat, always more extensive than the urban area where certain species exist.

→ **Instead of doing more, we need to do less.** It is necessary to change the way green infrastructures are managed within cities, based mainly on aesthetic criteria. It is important to let nature reconquer urban spaces, abandoning the fixation on order and the "cleanliness" of green areas. On the contrary, we must conserve the biomass that allows ecological succession and maintain ecosystem services, as vital as pollination, that have spatial dynamics of regional scope.

→ A flock of common kestrels flying over the Tres Puentes wetland in Punta Arenas, Patagonia, Chile.

Photo: Luis Inostroza.

↓ Flamingos in a Patagonian steppe lagoon.

Photo: Sebastián Saiter.

The biodiversity of urban wetlands can occasionally exceed that of non-urban wetlands.