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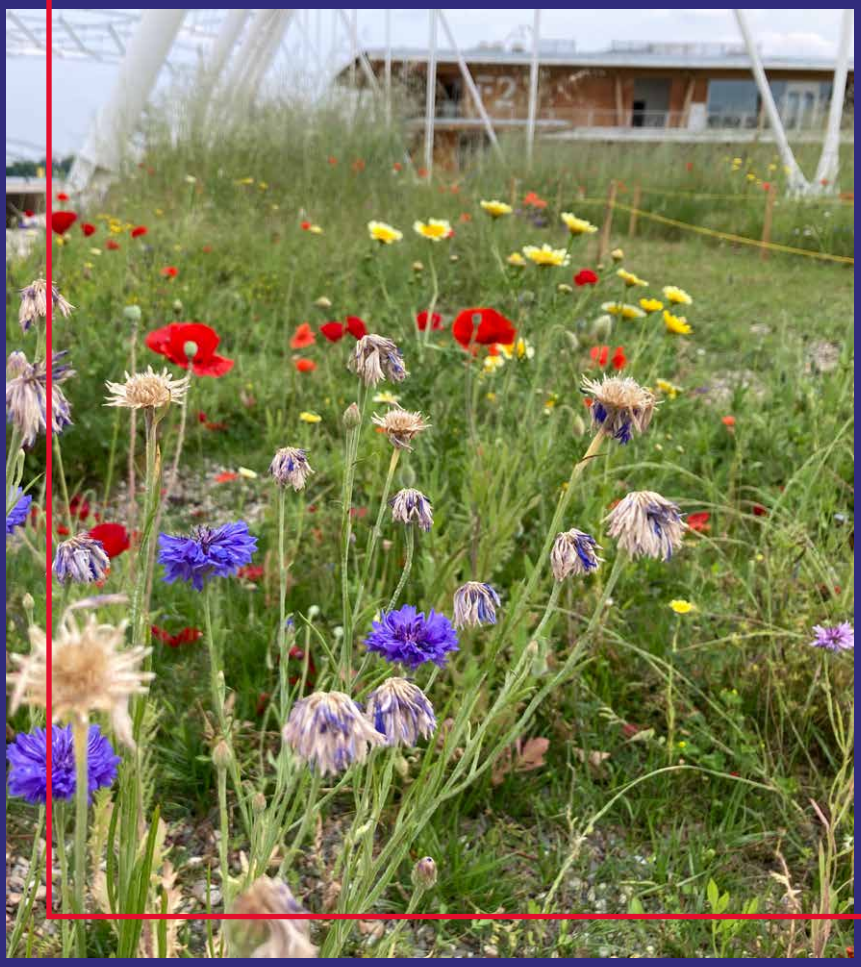

BIOSCOPIUM

Guidelines for mapping urban biodiversity in urban regeneration areas

T-FACTOR
PARTICIPATORY FUTURES
CO-CREATING CITIES THROUGH MEANWHILE SPACES

T-FACTOR HAS RECEIVED FUNDING UNDER HORIZON 2020 RESEARCH & INNOVATION PROGRAMME WITH GRANT AGREEMENT NO. 868887

/CREDITS

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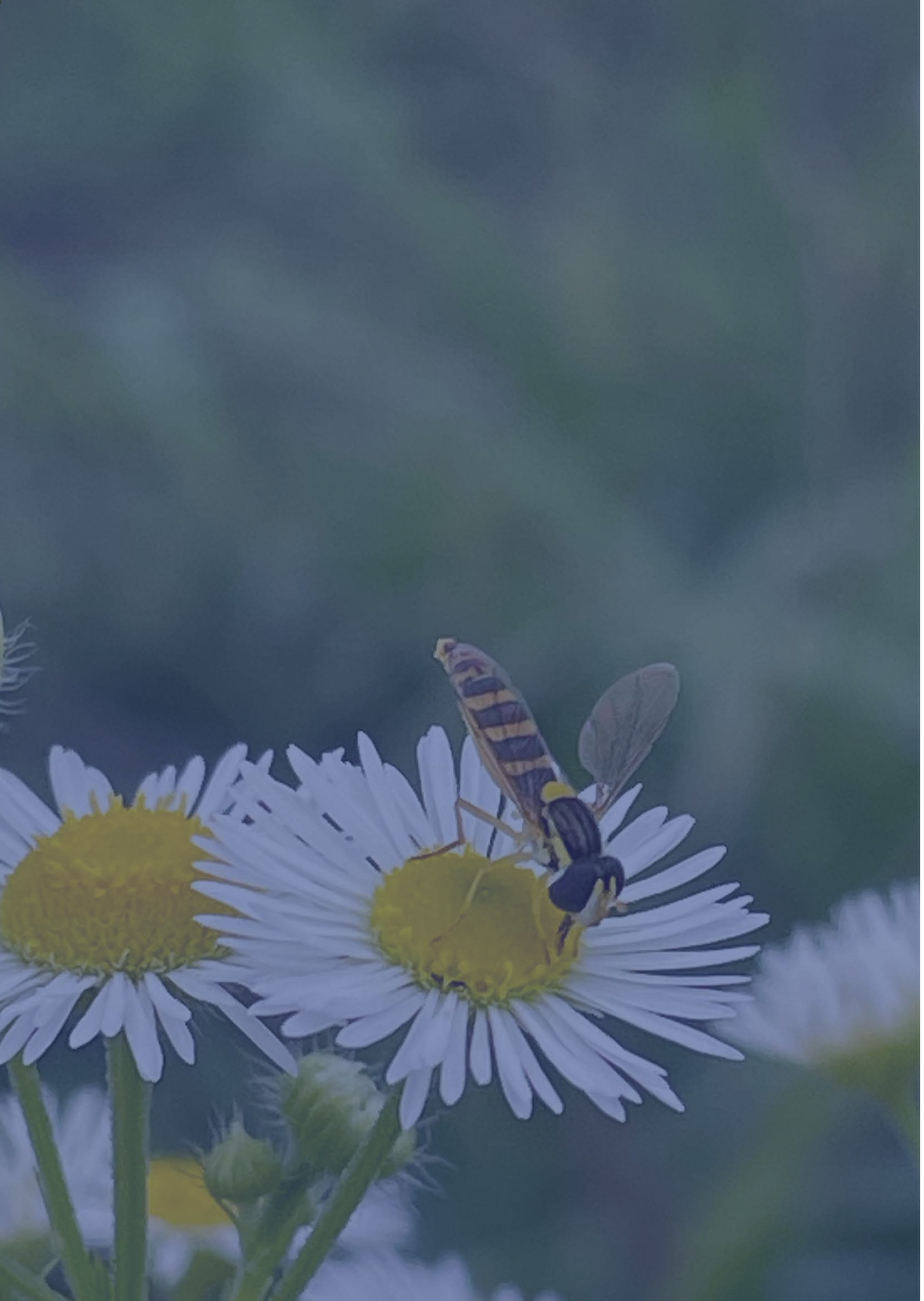

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/ABOUT THE GUIDELINES

/ABOUT THE GUIDELINES

Urban biodiversity is an oxymoron in today's cultural context, but biodiversity is a crucial aspect of our cities' environments, societies, economies, governance, and cultures.

Today's challenges related to climate change and the loss of biodiversity in the territories and green spaces of cities should be tackled with the awareness that designing with nature is a local, regional and global emergency. Cities are called upon to take the lead in promoting the conservation of biodiversity, but also its implementation in urban open spaces.

Researching the value of Biodiversity in urban regeneration contexts is part of the theme of the use of the natural resources of our territory; it is necessary to consider the effects of social and economic impacts on our environment and especially on the numerous species that populate it. It is, therefore, necessary to investigate the role of biodiversity with respect to its peculiarities and challenges in urban regeneration settings. Assessing the loss of biodiversity in urban settings is a topic included in the ESG (Environmental, Social and Governance) dimension that can highlight the limitations of ESG models and also suggest some solutions. Biodiversity degradation (biodiversity loss) creates risks (physical, transitional and liability) for all companies and sectors in different ways and over time.

European Biodiversity strategies for 2030 [1] (2023) strongly marked a change in the European landscape on the issue of biodiversity. The European Union is directing planners, and decision makers towards strategies to be urgently included in urban and spatial regeneration plans with imminent, concrete and visible impacts by 2030. The EU Council emphasized the need to step up efforts to tackle the direct and indirect causes of biodiversity and natural resource loss. It reiterated the need to fully integrate biodiversity objectives into other sectors, such as agriculture, fisheries and forestry, and to ensure coherent implementation of EU measures in these areas. Hence, the need to map biodiversity in complex urban regeneration contexts raised in different urban contexts.

The guidelines for mapping Urban Biodiversity in urban regeneration areas collected in this report were created thanks to an experimental initiative - called Bioscopium - conducted within the T-Factor project from April 2023 to December 2023.

T-Factor[2] a Horizon 2020 research and innovation project funded by the European Commission with grant agreement n. 868887, aimed to demonstrate the transformative potential of temporary uses as part of urban regeneration initiatives across six pilot projects in Europe as critical assets for the city to establish more inclusive and sustainable regeneration processes.

1. https://www.consilium.europa.eu/en/policies/biodiversity/#2030

2. www.t-factor.eu

Photo credits: LAND

The Bioscopium initiative

Bioscopium was conceived as one of the initiatives developed by T-Factor for the pilot project of Milan, MIND - Milano Innovation District, by the researchers of Polifactory - Department of Design - Politecnico di Milano and LAND Italia, in collaboration with agronomists and wildlife experts of Studio TerraViva.

Bioscopium's ambition is to experiment with an innovative wildlife biodiversity mapping system to support developers, policymakers and other decision-makers involved in regeneration projects in knowing, preserving and implementing wildlife in the area under regeneration and during the regeneration process, as a crucial factor for environmental quality and human wellbeing.

More specifically, the project aims to test a system for exploring urban biodiversity in regeneration contexts to:

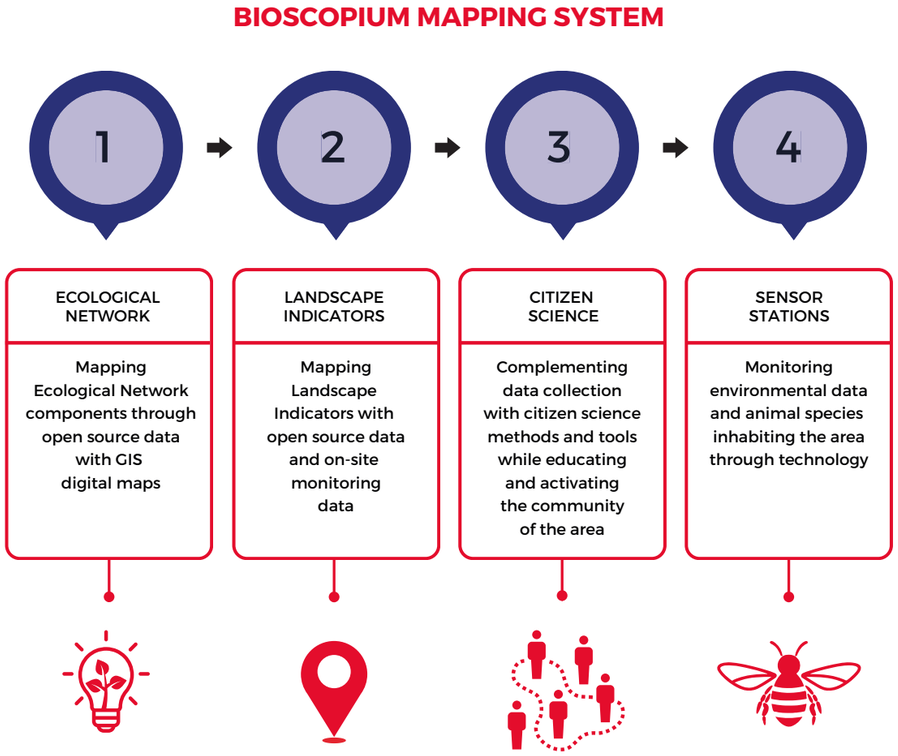
- understand the impact of the masterplan on the habitats present in the area during the regeneration period;
- inform and sensitize developers and public authorities on biodiversity issues;
- engage and activate citizens in biodiversity-related activities
- implement biodiversity with strategic actions and green management guidelines.

In order to give decision-makers comprehensive information about the natural state of the area (both inside its borders and in relation to the surrounding territory), and to support experts engaged in monitoring tasks, Bioscopium envisions a mapping system that integrates distinct mapping actions:

- Mapping of the Ecological Network and Landscape indicators, from territorial to local scale, through the analysis of open source data and their visualization on digital maps through GIS software[3];
- Gathering and visualizing biodiversity observations with citizen science methods and tools for complementing the data collection while activating and educating the community of the area.
- Monitoring with sensor stations for the collection of environmental data and the observation of faunal species inhabiting the area under regeneration;

3. "A geographic information system (GIS) is a computer system for capturing, storing, checking, and displaying data related to positions on Earth's surface. GIS can show many different kinds of data on one map, such as streets, buildings, and vegetation. This enables people to more easily see, analyze, and understand patterns and relationships" (Source: *https://education.nationalgeographic.org/*).

<< Photo credits: Polifactory



Specifically, Bioscopium's sensor stations are inspired by the so-called Automated Multisensor Stations for Monitoring of species Diversity (AMMODs), which involve the integration of various technological components such as bioacoustic sensors, customized imaging systems, automated image analysis, DNA-barcoding, volatile organic compound analysis and discriminators to distinguish species on the basis of their intrinsic characteristics, such as movement and speed (see e.g. Wägele et al., 2022). More in depth, they are designed in a modular way to be configured and personalized each time according to the biotope to be monitored, and to overcome the current limitations posed by the monitoring through human observations or the use of photo-traps, or by weather stations alone. (see section 1.4). Each module serves a specific function depending on the type of camera, sensor or actuator it is endowed with and the class of animals it intends to detect: insects, mammals, birds, fishes or amphibians. In general, each station is aimed to detect the number, type and variety of a specific class of animals present in the area over time, together with environmental data such as soil moisture, water quality, air temperature, pressure and humidity.

Also, depending on the vastness and variety of the context to be monitored, the system can make use of a variable number of sensor stations, each one composed by different modules depending on the location where it is positioned and the classes of animals it is decided to monitor.

Based on the features of the Bioscopium mapping system and the implementation of the first prototype of the sensor stations, both of them experimented at MIND - Milano Innovation District, it was possible to extract some guidelines to be used by others in similar urban regeneration projects. Despite the Bioscopium system requiring further development and validation, we believe the experience at MIND allowed us to mature a good practice toward a new model for retrieving knowledge on urban biodiversity that, at the same time, facilitates engagement, education and action. The Guidelines seek to disseminate the knowledge acquired by Bioscopium's experiments at MIND in order to further the conversation about urban biodiversity and establish it as a necessary component of any future urban development.

Purpose of the guidelines

The primary goal of setting guidelines is to give stakeholders of urban regeneration initiatives a workable approach and instruments that will enable biodiversity mapping to become a routine and essential procedure for a just reconstruction where the interests of people and the environment coexist.

Although key decision-makers will continue to play a crucial role in commissioning or initiating the mapping process, the guidelines are aimed at a wider range of actors who can independently and spontaneously carry out some complementary activities.

Further to this perspective, the potential target groups of these guidelines are the following:

- **Real estate developers** who may influence the masterplan's execution standards and biodiversity conservation;
- **Public officials** capable of putting into practice suitable regulations targeted at strategic initiatives for the promotion of local biodiversity;
- **Specialists in biodiversity** (such as agronomists and animal conservationists) who are able to define, coordinate, carry

out, and interpret mapping operations;

- **Professionals** with expertise in urban regeneration, environmental issues as landscape architects and urban planners, who are able to identify and create plans of action for effectively managing and promoting the region's urban biodiversity;
- **Non-experts and citizens** who can help with data gathering, support citizen-science initiatives to promote biodiversity, and maintain natural areas include neighborhood associations, local communities, and private citizens.

For each of these beneficiaries, specific **objectives** of the guidelines are:

1. **to support the raising of awareness and knowledge of urban biodiversity**, through both scientific and popular contents, as a factor of environmental quality and human well-being, as well as marking its cultural and educational value for cities and their inhabitants;
2. **to provide some methodological steps** to be followed for mapping biodiversity in complex urban regeneration contexts, which consider the area under regeneration in relation with the wider ecological network;
3. **to exploit available open-source systems and resources** as the starting source of information on which to build biodiversity mapping strategies;
4. **to integrate the mapping work** performed by experts with tools and resources that help increment in both efficiency and frequency the mapping activities throughout the regeneration period;
5. **to facilitate the creation of an ecosystem of biodiversity-sensitive actors** that collaborate for the common purpose of firstly knowing and then promoting local biodiversity;
6. **to suggest possible actions to be undertaken in order to preserve, protect or enrich the biodiversity** in the area under regeneration, in synergy with the wider urban context.

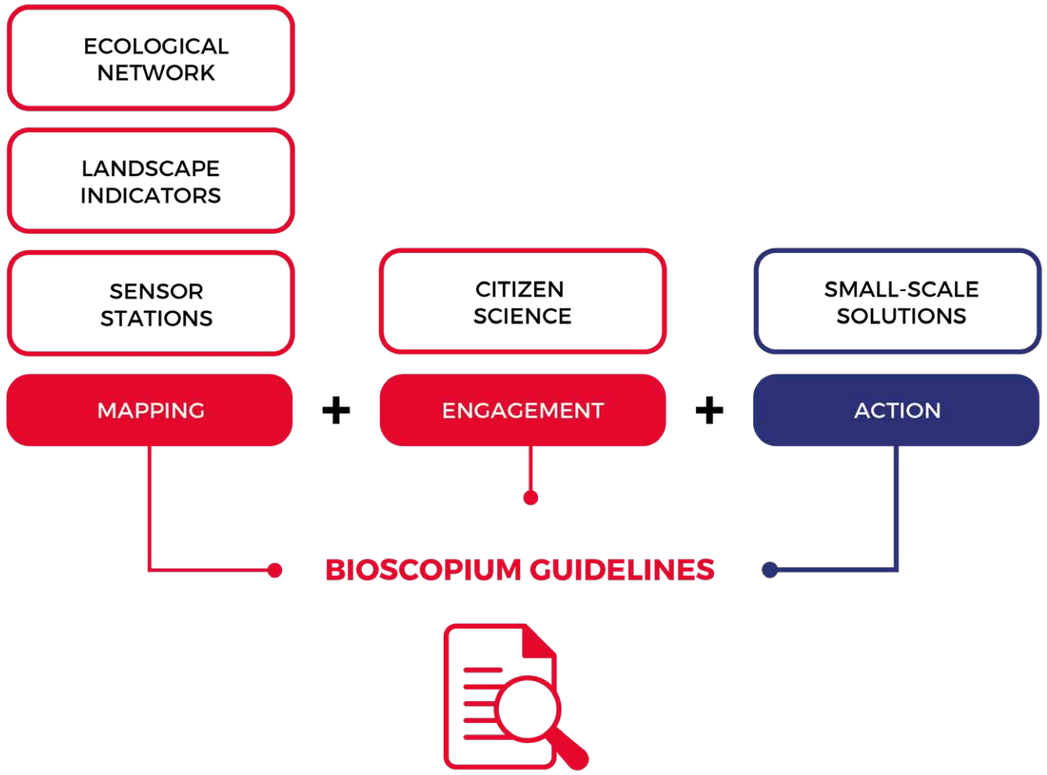
>> Photo credits: LAND

Structure of the guidelines

After an introduction discussing the function and significance of biodiversity in urban environments, and a glossary section which could provide definitions of important terminology on urban biodiversity, the guidelines are organized as follows:

1. **Mapping guidelines**, including guidelines for mapping the ecological network from territorial to local scale through the analysis of open source data, through the involvement of wildlife experts, and through the use of sensor stations;
2. **Engagement guidelines**, for involving groups of non-experts in data collection, according to a citizen science approach, to complement what experts and the technology detect, while educating, at the same time, local stakeholders and communities;
3. **Action guidelines**, for identifying appropriate small-scale solutions to improve biodiversity in the regeneration context according to the results of the mapping and the engagement, which can be suggested to developers and decision-makers toward the development of a biodiversity-aware regeneration strategy.

As follows, the case of T-Factor's milanese pilot projects, MIND - Milano Innovation District, is described in the Annex, to exemplify how the guidelines can be applied to a real urban context under regeneration.



/GLOSSARY

/BIODIVERSITY

The term biodiversity is defined by the Convention on Biological Diversity (CBD) as the ***'variability among living organisms from all sources including, inter alia, terrestrial, marine and aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species and between ecosystems***'. Biodiversity is generally studied on three different levels, which correspond to three levels of organisation of the living world: that of genes, that of species and that of ecosystems (ISPRA[4]).

/BIOTOPES

In ecology, a biotope is defined as a limited area of an environment where plant and animal organisms of the same or different species live, which together form a biocenosis. The biotope is ,therefore, the component of the ecosystem characterized by abiotic (non-living) factors, such as soil or substrate, with its physical and chemical characteristics, temperature, humidity, light and so on, but not considered separate from the biological component.

/ECOLOGICAL CORRIDORS

Landscape element that connects two or more patches of natural habitat. It serves as a habitat and channel for the movement of animals and spores and as an area through which genetic exchange between populations takes place *(Adapted from ISPRA).*

/ECOLOGICAL NETWORK

The ecological network as an interconnected system of habitats, whose biodiversity must be safeguarded*, thus paying attention to potentially threatened animal and plant species.* The ecological network are made by:

- ***Core areas****:* high nature areas that are already, or can be, subject to a protection regime (parks or reserves) buffer zones;
- ***Buffer zones,*** or transition zones, located around high nature areas in order to ensure the necessary gradual establishment of habitats;
- ***Connecting strips (ecological corridors)****:* linear and continuous landscape structures that connect high nature areas and represent the key element of ecological networks as they allow species mobility and genetic exchange, which is indispensable for maintaining biodiversity;
- ***Nodes and Stepping stones/zones****:* areas of small surface area that, due to their strategic position or composition, represent important elements of the landscape to support species in transit through an area or host particular micro-environments in critical habitat situations *(e.g. small ponds in agricultural areas (ISPRA).*

/ECOSYSTEMS

The totality of communities of animal and plant organisms and the environment in which they live and interact. Examples of ecosystems are a lake, a forest, a coral reef *(ISPRA).*

/ECOSYSTEM SERVICES

According to Millennium Ecosystem Assessment are the multiple benefits provided by ecosystems to humankind. ES are set in four categories: supporting (such as nutrient cycling, soil formation and primary production), provisioning (such as the production of food, drinking water, materials or fuel), regulating (such as climate and tidal regulation, water purification, pollination and pest control), cultural values (including aesthetic, spiritual, educational and recreational). Relevant is the role of ecosystem services with respect to their connection to society *(MEA).*

/GANGLIA

Ganglia are those natural units capable of constituting, in terms of size and internal articulation, ecosystem strongholds capable of self-sustaining themselves. That is, they must be able to provide a habitat, sufficient to maintain stable populations of the species of interest, and allow differentiation of internal habitats so as to improve conditions for biodiversity. Ganglia can be primary and secondary depending on their function within the ecological network *(Adapted from ISPRA).*

/HABITAT

Set of physical (e.g. light and temperature) and chemical (e.g. nutrient concentration) environmental conditions in which an organism grows and performs its vital functions. The set of organisms that inhabit a habitat is called a community *(ISPRA).*

/MAPPING URBAN BIODIVERSITY

Mapping is the act of representing information in maps. The map is a representation, usually on a flat surface, of the features of an area of the earth or a portion of the heavens, showing them in their respective forms, sizes, and relationships according to some convention of representation.

Specifically, ***Urban Biodiversity maps are a cartographic representation of any biodiversity data that have temporal and spatial units in relation to urban contexts***. The use of open-source data, from planning documents to citizen science, allows geo-reference information, surfaces and making evident spatial relationships that can represent the existing conditions of biodiversity in a place. Moreover, the collection of information and its systematization in cartography makes it possible to synthesize the complexity of urban biodiversity issues so as to make them comprehensible to all.

4. Italian Institute for Environmental Protection and Research - https://www.isprambiente.gov.it/

/GLOSSARY

/MONITORING

One of the ways in which ***environmental control*** is carried out is through monitoring, understood as the ***systematic verification*** of changes in a specific ***chemical, physical or equivalent parameter over time through repeated measurements and observations with appropriate frequency*** *(Adapted from ISPRA)*

/NODES

These are the ***areas of maximum naturalness and biodiversity, with the presence of one or more habitats and species of conservation interest at regional and supra-regional levels*** that must be conserved in order to maintain the viability of biological populations between the different nodes of the network. *(Adapted from ISPRA).*

/STEPPING STONES

In landscape ecology discipline, ***they are small habitat patches***; they can be natural components in the ecological network of corridors at the territorial scale. An ecological corridor is defined as a strong connection between habitat patches.

/TARGET SPECIES

Species with characteristics that allow the identification of a range of spatial and functional requirements that encompass those of all other species in an area/ ecosystem to be placed under protection.

1

/INTRODUCTION

/INTRODUCTION

1.1 What is urban biodiversity and why it matters

The diversity of life on Earth, encompassing all its forms and interactions, is known as biodiversity. Biodiversity encompasses microorganisms, plants, animals, and the natural systems that uphold them, and it characterizes our natural richness, shaping the living environment that surrounds us, supporting ecological systems, and enriching our overall quality of life. The preservation of biodiversity is a crucial resource for the resilience of ecological systems and, consequently, for the advancement of human societies (Folke et al., 2016). To date, approximately 25% of species face global threats, posing a substantial risk to food security (IPBES, 2019), and requiring efforts to mitigate climate change, the availability of energy resources, and the condition of ecosystem services.

If biodiversity can be defined, in simple terms, as the diversity of life on Earth, the term urban biodiversity refers to the wild nature hosted by our cities.

Urban environments deserve to be considered and enhanced as habitats for wildlife, both flora and fauna, since they serve two primary functions (Dinetti, 2009):

- **Direct functions** involve contributing to the conservation of local biodiversity and protecting certain threatened species of conservation interest, which find a suitable habitat within urban settings. The conservation of nature in cities is thus beneficial for biodiversity in a narrow sense, given the often high levels of biodiversity found in urban environments compared to the surrounding rural areas.
- **Indirect functions** encompass raising awareness and fostering a proper perception among citizens, particularly the youth, who reside in areas with depleted biodiversity, losing daily contact with nature.

Despite the scarcity of green spaces, cities serve as habitats for over 45,000 species, encompassing both native species, some typical of the surrounding areas, and others exclusive to urban environments. This diversity is attributed to the presence of varied biotopes (Sattler et al., 2011). Nonetheless, despite the remarkable biodiversity in urbanized environments, their conditions have a negative impact on nature as a whole (McKinney, 2002).

The presence and good condition of nature in cities is essential for the development of a sustainable quality of life and to increase people's awareness about it. Most people live in urban areas, and cities are the places where political decisions that affect the world's ecosystems are made. It is mainly in cities that people shape their perceptions of nature; thus, being in contact with nature in the place where people live and make decisions is essential to raise awareness of the importance of biodiversity globally.

For these reasons, the pressing importance of conserving biodiversity, coupled with the imperative to reintegrate nature into urban settings to create mutual advantages for both citizens and the environment, has turned cities into focal points for experimentation. Urban regeneration projects, in particular, because of their innovative and transformative nature, frequently serve as ideal platforms for these kinds of experiments (Gulsrud et al., 2018). They can vary from the implementation of strategies to conserve urban biodiversity, the restoration of habitats that bring target species back to the city (Obrist et al., 2013), and actions to improve people's affective and experiential connection with nature (Mayer and Frantz, 2004). Not to consider the benefits that direct contact with nature brings to people's well-being, as discussed in the next section.

1.2 | Biodiversity and well-being

According to the World Health Organisation (WHO, 2023), rapid urbanization, land use change, land degradation, global trade and industrialisation have caused a profound and negative impact on nature worldwide. The ongoing depletion of natural resources is affecting environmental conditions and has a huge impact on climate change, vector-borne diseases and zoonoses, food safety, water supply and pharmaceutical options. Also, it jeopardizes health, well-being and safety all around Europe. The importance of biodiversity for the daily lives of people and our planet was not only declared in the Convention on

Biological Diversity of Rio de Janeiro (1992), but more recently in the Kunming-Montreal Global Biodiversity Framework of COP15 and in the WEF 2022 BiodiverCities by 2030 report. According to the latest data collected by the European Centre for Environment and Health (WHO ECEH, 2023) and the United Nations Environment Programme (UNEP), it can be stated that it is necessary to redesign our urban spaces in a way that emphasizes the inescapable relationship between humans and nature, biodiversity and human well-being. Among the others:

- Nature and ecosystems provide important products such as water, energy, food and medicine as well as important services such as climate regulation, nutrient cycling, carbon storage and oxygen production;
- Up to 1 million species are threatened with extinction – many within a few decades. The loss of biodiversity affects our life support systems (e.g. food systems), which in turn has an impact on health and well-being;
- Over 80% of the world's wastewater is discharged untreated into the natural environment.
- In the European Union (EU), 39% of the land was used for agriculture in 2018, while only about a quarter was classified as “protected” in 2021, according to the OECD;
- Data from the European Environment Agency shows that agriculture, public water supply and tourism account for the largest share of water resource use. In southern Europe, around 30% of the population live in areas under permanent water stress;
- Around two thirds of the EU's wetlands have been lost in the last century, with 85% of the remaining wetlands having an unfavorable conservation status.

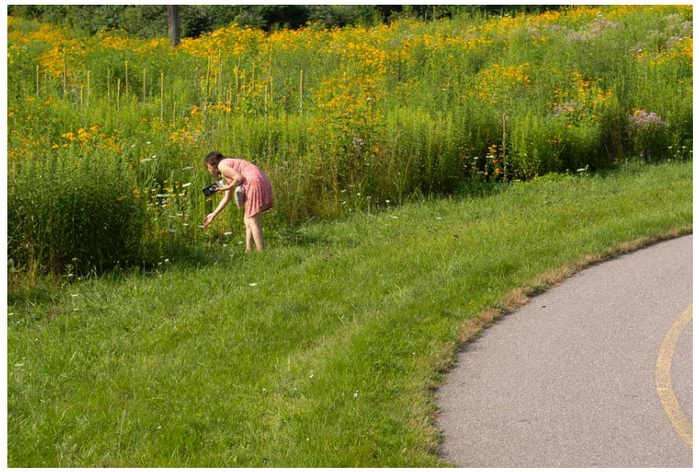
<< MIND Milano Innovation District - Herbula Wild garden
Photo Credits: LAND

Therefore, protecting nature and counteracting the loss of biodiversity and ecosystems, including in urban habitats, is a fundamental prerequisite for the health of future generations and is explicitly addressed by Sustainable Development Goals 14 and 15 on life below water and on land. Moreover, spending time in nature is associated with a lower risk of certain health conditions. Not to mention those studies that demonstrate that biodiverse environments, also called "restorative environments", are particularly effective in enhancing psychological well-

being, reducing both physical and mental stress, eliciting positive emotions, and aiding in the replenishment of cognitive resources (Bellini et al., 2015; Hartig, 2004).

This means that investing in the transition to green and sustainable societies and economies represents an investment in health and cultural capital too. Here stands the strongest reason for mapping urban biodiversity: finding the balance between the well-being of people and the planet, as one depends on the other and *vice versa*. As mentioned above, urban regeneration contexts can be considered the ideal context and opportunity to experiment on the adoption of some good practices.

>> Photo credits: The meadoway - Community powered green spaces



1.3 Biodiversity and urban regeneration

It is not a secret that urbanization has had a devastating impact on the world's biodiversity: according to data collected and surveyed by FAO (the Food and Agriculture Organization of the United Nations) from 1990 to 2020, out of a total of 4.06 billion hectares (about 31% of the earth's surface), some 186 million hectares of forests and woodlands have been destroyed,

replaced by permanent urbanization installations, such as infrastructure and buildings in the world's major megacities and metropolises.

The United Nations recently declared the 2020s the Decade for Ecosystem Restoration, calling on governments, institutions and citizens to rebuild degraded or destroyed natural habitats and conserve existing ones. Accordingly, as it can also be argued from the previous sections, international and national entities are formulating policies pertaining to urban biodiversity. Among the others, the Kunming-Montreal Global Biodiversity Framework (UN, 2022) guides the implementation of actions to revolutionize our relationship with biodiversity by 2030, advocating for local biodiversity policies that promote sustainable utilization and equitable sharing of its benefits, with a strong emphasis on awareness and education. Instead, the European Commission, through the New Biodiversity Strategy 2030 (EC, 2020), has urged cities with a population of at least 20,000 inhabitants to craft ambitious urban greening plans. These plans should encompass the creation of accessible and biodiversity-rich forests, parks, and gardens, as well as the implementation of green roofs and walls in urban regeneration contexts.

In the contexts of urban regeneration, the design and management of biodiversity should also ensure short- and long-term soil regeneration processes. In this perspective, the European Union has promoted the Soil Strategy 2030, aimed at mitigating soil use by monitoring the health of the soil also with respect to components that create biodiversity. Accordingly, the transformation of disused/neglected urban areas has long since assumed a key role. In Italy, for example, 920 square kilometers of regenerable soil will be available in the national context over the next 27 years. The vision of the potential of urban regeneration, not only in real estate terms, but also at environmental, social and economic level was expressed in the 'National Report on Urban Regeneration (Unipol, 2023)'. However, the environmental and biodiversity dimension in these planning instruments is still weak and ancillary to the environmental sustainability challenges still facing the performance of the city's buildings and services.

Inventive actions are, therefore, needed that seek to integrate urban biodiversity into concrete regeneration operations. The significance of urban biodiversity projects lies in the provision of a range of ecosystem services, such as urban-rural soil regeneration, climate regulation, air and water purification, pollination, and aesthetic benefits planning for cities. Thus, environmental protection and the design of ecological corridors and green infrastructure (European Commission, 2018) are increasingly considered priority actions in urban regeneration strategies across Europe. Moreover, green corridors, which are interconnected strips of green spaces linking urban areas with natural habitats, have become popular in European cities as a nature-based solution[5] to promote urban biodiversity.

As declared by most regional landscape plans and green papers (at least in the European context), the design of biodiverse habitats and ecosystems in urban regeneration contexts should also include the careful selection of plant species such as native plants and wildlife-friendly plants in private and public gardens. These small but necessary design actions will contribute to the sustenance and maintenance of local urban biodiversity as native plants are adapted to local conditions and provide food and habitat for local wildlife, also considering that they have minimal water requirements compared to allochthonous and alien species (EU, 2020).

Certain cities are exploring innovative green placemaking strategies, particularly in the context of regeneration initiatives. One noteworthy example is the Natural Park of Lama Balice in Bari, Italy (Tarsitano et al., 2021), where cultural and social interventions, such as sensory labyrinths, vegetable gardens, and natural architectures, have been employed to restore biodiversity. These interventions aim to enhance citizens' quality of life while upholding principles of sustainability and social participation. Similarly, the Tempelhofer Feld Initiative in Berlin, Germany, has transformed a former airport area into a space dedicated to biodiversity recreation and protection. The city has implemented a maintenance plan for the area, fostering cooperation with citizens.

5. Nature-based solutions encompass measures aimed at safeguarding, preserving, restoring, and sustainably utilizing natural or altered terrestrial, freshwater, coastal, and marine ecosystems. These actions are designed to tackle challenges that span social, economic, and environmental dimensions, as articulated in the Fifth session of the United Nations Environment Assembly (UNEA-5, 2022).

>> Biodiversity Corridor Montrèal - Canada, Photo credits: LAND

>> Lama Balice Park, Bari, Italy, Photo credits: Italian Botanical heritage

These endeavors exemplify actions bridging humans and biodiversity. But to establish a better balance between the two, humans firstly need to know what biodiversity is present (or should, or could be present) in a certain urban area, that is to perform biodiversity mapping and monitoring. And here comes the work of experts that, with more or less support from available technologies, are called to provide urban planners and real estate developers with such knowledge. This is not an easy task, and the often scarce awareness of decision-makers, together with the even more scarce availability of resources, and the limitations of existing methods and tools, frequently make biodiversity mapping and monitoring a sporadic and optional practice. The Bioscopium system, together with the guidelines collected in this document, try to overcome some of these limitations, which are summarized in the next section.

1.4 Mapping and technology limitations

Biodiversity mapping, or censusing and monitoring is a procedure normally led by ecology experts, time-consuming and highly difficult and time-consuming, which, and for these reasons, is often not carried out in fragmented urban areas. A partial and time-limited mapping of areas are sometimes preferred over the proper execution of field collection due to the time and expense involved in gathering data and the lack of necessary knowledge. To facilitate data collection, and to avoid experts to spend lot of time on field for the sake of direct observations, several tools and techniques have been developed for wildlife mapping and monitoring, also including the support of amateurs and non-experts. The most common and diffused is probably image capture through photo-traps, which is a powerful tool. for estimates of population densities, body sizes, and behavior. For small mammals, Littlewood et al. (2021) attached a camera to a baited tunnel, a method that can replace live-trapping typically used for monitoring of rodents. Other applications have been invented, for example to discover and count pest insects attracted to pheromone traps, yellow pans or bucket traps.

However, phototrapping is endowed with some limitations that do not allow for an extensive and systematic application. They include limited camera coverage (resulting in decreased probability of detection), the possibility to detect species only above a certain body size,, and the need for human intervention in both maintenance (replacing batteries, downloading data, repositioning the device) as well as identification, counting, and classification of images.

These constraints, in addition to the often limited availability of open-source data on the conditions of ecosystems in the surveyed areas, turn biodiversity mapping and monitoring in a sporadic action, mainly conducted for satisfying mandatory

<< MIND Milano Innovation District - Herbula Wild Garden, Photo credits: LAND

regulatory standards rather than a genuine interest in the sort of the environment. As a consequence, this results in the limited access to monitoring data and records, especially when carried out by property developers or private entities, which further increases the fragmentation of information and the difficulties in lowering the efforts for conducting such actions.

Today, mapping by means of image capture and recognition with autonomous systems for species detection[6] represents the most promising way to reduce human effort and is becoming more and more technologically advanced. Standards related to data collection protocols (such as type of camera used, positioning, species nomenclature) have been proposed that allow the comparison of data from different projects (Forrester et al., 2016). These technologies combined with participatory practices, such as those proposed by citizen science, could improve data collection results and reduce human effort (Ji et al., 2013; Elbrecht et al., 2017).

6. See e.g. Wildlife Insights (*www.wildlifeinsights.org*) or Bat conservation Trust (*https://www.bats.org.uk/*)

In our vision, integrating data collection (performed by experts with the support of advanced data capturing technologies, such as the Bioscopium sensor stations) and open-source image recognition systems, together with citizen involvement by means of citizen science, can make biodiversity mapping and monitoring a more accessible, continuous and participatory practice. We believe this strategy could compensate for the time, costs and limitations of expert work alone, while at the same time activating communities, raising awareness, and supporting data standardisation, digitisation and openness, toward a more continuous, systematic, and extended mapping and monitoring at urban level.

1.5 Working together with local organizations, experts, and exploiting citizen science

As mentioned above, mapping urban biodiversity in areas under regeneration in the way suggested by these guidelines entails the involvement and participation of several actors from the urban ecosystem. We strongly believe that, to make urban biodiversity a priority in the future regeneration agendas, it will be increasingly important to make it a common affair, starting from making it easier to perform and access (as proposed by the Bioscopium initiative), and then pushing local stakeholders, experts, and citizens working together toward a shared purpose. To do so, each one should cover a specific role and function in the mapping process suggested as follows, starting from that of *biodiversity steward*, i.e. the individual, group or organization that acts as promoter of the biodiversity mapping and is responsible for bringing the issue to the attention of decision-makers, as well as finding and organizing the resources needed for data collection and its subsequent use.

In the context of urban regeneration, this role should ideally be covered by the developer or local authorities, but if not triggered by them it could eventually be appointed to other local actors such as:

- stakeholders of the area under regeneration (e.g. companies sensitive to the issue);
- environmental associations, activists, networks of nature experts based in the urban context;
- cultural associations, youth associations, etc., operating in proximity to the regeneration area;
- local public institutions operating close or in connection to the area under regeneration;
- organized groups of citizens living nearby, etc...

Of course, decision-makers of the area will keep on playing their decisional role by authorizing the mapping, providing access to the area and to data already available, as well as participating

in defining the solutions in support of biodiversity to be implemented.

While the above-mentioned actors, if not playing the steward role, could be involved in the mapping process with other roles and tasks, which could span from supporting the work of experts (which will remain fundamental) by providing data about the territory, developing and organizing engagement activities, or implementing actions and solutions for preserving and improving biodiversity as those described in the dedicated sections of these guidelines.

>> Mapping Biodiveristy with citizen at MIND - Milan Innovation District. Photo credits: Polifactory

A further discourse should then be devoted to cooperation with local communities or individual citizens. Their role in the mapping could be defined as "active beneficiaries". In fact, building on the EU Biodiversity Strategy for 2030, it is suggested to make citizens play an active role in the mapping process, and not only make them take advantage of the benefits brought about by direct contact with nature in the city. This active role can include their involvement in the implementation of strategies to promote biodiversity in private spaces, and participatory practices in data collection and monitoring of urban green spaces through citizen science and educational programmes.

Citizen science, indeed, is a research methodology conducted with the participation of the general public, amateur/non-professional researchers in ecology, biology and conservation sciences. In urban regeneration contexts, citizen science activities can contribute substantially to urban biodiversity analysis and monitoring practices. For this reason, an entire section of the guidelines is dedicated to the engagement of non-experts in mapping activities, and citizen science represents the key approach for making this happen.

<< Biodiversity mapping with citizens at MIND - Milano Innovation District. Photo credits: LAND

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