



Urban biodiversity and design in time of (post)pandemics: research perspectives from URBIO international network

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Abstract

Reflecting on the insights from research development within Urban Biodiversity and Design Network (URBIO), this paper attempts to link the consequences of current global changes (ongoing urbanization, biodiversity loss, land-use changes, globalization, etc.) to the emergence and outbreaks of the COVID-19 pandemic. It analyses the main outcomes of the URBIO webinar (December 2021) and the URBIO conference (November 2022) and the results of the questionnaire survey among the URBIO experts on the impact of COVID-19 on the biodiversity, design and society in their local contexts as well as on the ongoing and future URBIO research directions. The survey also enabled to explore and assess a wide diversity of human-nature interactions as well as the novel actions and adaptation strategies established to have positive outcomes for both humans and nature. The results revealed the following aspects associated with the COVID-19 pandemic: silence, social distancing, isolation, conflict ideologies, and declined recreational and other human activities. Experts noticed the increase of urban green space visitation and interest in nature. The majority of the experts confirmed the impact (both positive and negative) of the COVID-19 on biodiversity and environment. General positive aspects refer to the value/significance of nature and biodiversity/wildlife and especially the contact with nature (“time outdoor”, “time spent with family”, “inspiration from nature” and “enjoying nature”). The positive consequence of the COVID-19 measures was also the improvement of wildlife habitats and the increase of spontaneous flora as well as fauna species. Experts confirmed the lower/decreased level of pollution, noise, traffic, light, anthropogenic pressure/impact, number of tourists, vehicles as well as less garbage. The analysis of leading research themes among the URBIO conference participants confirmed that the biggest number of presenters and participants were on the topic of biodiversity integration in urban planning, green infrastructure, and landscape design projects. Another popular theme was ecological restoration and urban wildlife and plant biodiversity. One particular research direction that emerged recently and clearly pronounced at URBIO 2022 was urban biodiversity in times of climate change and post-pandemics.

Keywords Urban biodiversity · Design · Global change · COVID-19 pandemic · Human-nature interactions · Adaptation strategies · URBIO (Urban Biodiversity and Design International Network)

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Introduction

The impact of the COVID-19 pandemic is observed in each sphere of human society, which led to not only a health emergency and socio-economic crises, but also paradigm shift to the COVID-related research and management (Ramvilas et al. 2021). The latter has influenced different scientific domains, including research in urban biodiversity, urban planning and design. The coronavirus (COVID-19) pandemic has caused an enormous negative impact worldwide associated with high mortality rates, global physical and mental health effects, lockdowns, social distancing as well as global socio-economic crisis due to pandemic-induced loss of jobs and income. There are several strategies that cities worldwide have developed to cope, react and respond to the crises caused by COVID-19 following the declaration of the World Health Organisation (WHO) measures. Among them are various restrictions aiming to slow or prevent the spread of COVID-19, however, they greatly impacted individual mobility and public life mainly through limited access to services and facilities as well as causing the lower intensity of people's daily physical activity. In many cases, it also resulted in limited access to urban nature due to the closure of some public parks and other open spaces to help encourage physical distancing (Dushkova et al. 2021; Kleinschroth and Kowarik 2020). The significant number of studies indicated the importance of regular contact with nature and biodiversity in cities for human well-being and shaping human-nature relationships and the recovery during the COVID-19 as well as in the post-pandemic world (Ahmadpoor and Shahab 2021; Barton et al. 2020; Dushkova et al. 2022; Grima et al. 2020). Moreover, contact with nature within local neighborhoods during the pandemic appears to play an essential role than ever not only in providing outdoor activities but also in allowing secure socializing and supporting psychological well-being (Ahmadpoor and Shahab 2021; Da Schio et al. 2021; Dushkova et al. 2021). A great number of studies highlighted that the quality of urban green spaces and their availability, the aspects of biodiversity (McNeely 2021; Morand and Lajaunie 2021) as well as green planning and landscape design characteristics should receive special attention (Graziano 2021; Mouratidis 2021; Sharifi and Khavarian-Garmsir 2020; Soga et al. 2021; UN Habitat 2021). These studies also recommended further investigation of the effects of the COVID-19 pandemic on the use and perceptions of urban nature and diverse green space (Ahmadpoor and Shahab 2021; Dushkova et al. 2021; Grima et al. 2020; Kleinschroth and Kowarik 2020; Pouso et al. 2021; Slater et al. 2020; Ugolini et al. 2020), urban green space accessibility and availability / walkable community (Barton et al. 2020; Finnsson 2020; Slater et al. 2020; Uchiyama and Kohsaka 2020), value of

urban green spaces from the planners' perspective (Ahmadpoor and Shahab 2021; Kleinschroth and Kowarik 2020) along with biodiversity-sensitive design principles (Giles-Corti et al. 2023; Oke et al. 2021; Zhang et al. 2021).

In the context of the extraordinary situation caused by the COVID-19 pandemic, and considering the role that the Urban Biodiversity and Design Network (URBIO) can play in strengthening the knowledge base on urban biodiversity and design during and after the COVID-19 pandemic, the chairs and advisory board of URBIO organised an online webinar (9 December 2021) followed by a hybrid format conference (28–30 November 2022) on integrating biodiversity in urban planning and design processes. Both, the webinar and conference provided an opportunity to review worldwide the scientific evidence on the impact of the COVID-19 pandemic on the urban ecosystems and human lifestyle as well as the strategies developed in the research and practices at different levels (national, regional and local) to cope with the crises and better adaptation to the new reality.

URBIO (International Network Urban Biodiversity and Design) was founded in 2008 to promote urban biodiversity and design through a continuing dialogue with the Convention on Biological Diversity (Müller and Kamada 2011). The first conference took place in the same year in Erfurt (Germany); since that time seven international conferences and two webinars have been organized. URBIO's activities include the holding of a website (www.urbionetwork.com/), distribution of a URBIO newsletter, organization of international conferences, workshops, and seminars, publishing academic books (including milestone book, "Urban Biodiversity and Design" (Müller et al. 2010) and special peer-reviewed journal issues (e.g. in *Landscape & Ecological Engineering*, *Urban Forestry and Urban greening*, *LAND*, *Sustainability*, *Forest, Diversity*, etc.), and URBIO conference proceedings (Müller et al. 2008; Imanishi and Hon 2010; Gundimeda 2012; Müller and Kümmerling 2013; Kim 2014; Müller and Elsner 2016; Ignatieva et al. 2023) as well as developing research collaborations. Currently, the URBIO Network includes about 1150 participants from over 80 countries. URBIO has a unique inter- and transdisciplinary character and involves researchers in urban ecology, botany, geography, landscape architecture, and urban planning as well as practitioners and policymakers. As a result of such collaboration, several tools, e.g. the City Biodiversity Index (Chan et al. 2020), the URBIO Index (Müller and Elsner 2016), and the Cities and Biodiversity Outlook (Elmqvist et al. 2013, Schultz and Elmqvist 2014), were developed by the URBIO network members to support local authorities and practitioners (see more details in Müller and Werner 2023). Among other URBIO network activities are developing, maintaining, and supporting different scientific

programs, platforms, and publications, “Nature of Cities” Forum, TEEB – “The Economics of Ecosystems and Biodiversity for Local and Regional Policy Makers”, URBIO Research Agenda on Urban Biodiversity, Ecosystem Services and Design. The URBIO network actively collaborates with various affiliated scientific societies and working groups and is a member of the Global Partnership on Cities and Biodiversity founded with the secretariat of the CBD, the United Nations Environment Programme (UNEP), the United Nations Human Settlements Programme (UN-HABITAT), the Council for Local Environmental Initiatives (ICLEI) and its Local Action for Biodiversity program, the International Union for Conservation of Nature (IUCN) Countdown 2010, the United Nations Educational, Scientific, and Cultural Organization (UNESCO), several academic institutes and the cities of Curitiba, Bonn, Nagoya, Montreal and the City-State of Singapore (Müller and Werner 2023, in this SI).

In this paper, we reflect on the insights from research by URBIO network participants linking consequences of current global changes (ongoing urbanisation, biodiversity loss, land-use changes, globalization, etc.) to the emergence and outbreaks of the COVID-19 pandemic. Based on the responses of the URBIO network’s experts, we then discuss the impact of COVID-19 in different local contexts as well as analyse the variety of approaches developed to address the impact of COVID-19 as well as highlight areas for future action and research directions in the field of urban biodiversity and design. This paper analyses the main outcomes of the URBIO webinar (2021), conference (2022) and the results of the questionnaire survey among the URBIO experts on the impact of COVID-19 on the biodiversity, design, and society in their local contexts as well as on the ongoing and future URBIO research directions, especially on the interlinkages among biodiversity, urban planning, design, human health and well-being. The survey also enabled us to explore and assess a wide diversity of human-nature interactions as well as the novel actions and adaptation strategies for both humans and nature.

Materials and methods

Survey

To summarize the lessons learned from the current research on urban biodiversity and the environment in cities worldwide and the impact of (post) COVID-19 pandemic on them, the online questionnaire survey among the members (experts) of the URBIO network was conducted from 5 November to 5 December 2021 (first survey, 35 experts took part) and from 28 November 2022 to 28 February 2023

(second survey, 36 experts completed the survey). The questionnaire survey was created using Google forms and sent to the members (experts) of URBIO via email invitations. Methodologically, both surveys included similar questions listed in Supplementary material, however, the second survey included two more additional questions on the feedback to the URBIO conference.

The survey consisted of 13 open and closed questions around the following topics:

- Impact of COVID-19 on the city (in general).
- Positive and negative impact of the COVID-19 pandemic on urban biodiversity and the environment in the city.
- The most important topic of the research linked to COVID-19 pandemics and urban biodiversity in the local context.
- Involvement in the certain field of research on urban biodiversity and design now and within the next year(s).
- Main directions and topics for future research of URBIO network.

In total, 71 URBIO members (experts) took part in the survey from 20 countries representing all continents.

Survey responses were analyzed using the content analysis method (Drisko and Maschi 2016; Stemler 2001). First, keywords were highlighted, then keywords were grouped into key topics identified by the respondents. Key topics were used to analyze the most important topics of the research linked to COVID-19 pandemics and urban biodiversity in the local context/country (the total number of answers – 54). We applied word clouds to provide a fast and rich assessment of the most prominent keywords used by respondents in their responses to open-ended questions (McNaught & Paul, 2010). Based on the frequency of keyword mentions, the word clouds were created using Word cloud software from <https://wordscound.pythonanywhere.com/> on the following topics: COVID-19 impact on a city (total number of answers – 63); the positive impact of the COVID-19 pandemic on urban biodiversity and the environment in the city (total number of answers – 63); the negative impact of the COVID-19 pandemic on urban biodiversity and the environment in the city (total number of answers – 63).

URBIO webinar

URBIO Webinar on the 9 December 2021 “Urban Biodiversity and Design in Time of Pandemics” was organized online and based on 9 presentations of URBIO researchers and following discussion. 42 participants from 14 countries attended the webinar. Presented talks from different parts of the world (Japan, Korea, India, USA, Columbia, European

Webinar 9th of December

- Urban Biodiversity and Design in Time of Pandemics
- Presentations (up to 12 min with questions):
- The role of URBIO and the connection to CBD activity: Oliver Hillel
- Presentations
- **Roundtable Discussion**
- short updates on ongoing and planning research
- analysis of the survey results (Diana Dushkova (UFZ)) and discussion with the participants
- URBIO Conference 2022 in Berlin update: Notes from host institutions: Dagmar Haase, HU Berlin and Diana Dushkova, UFZ Leipzig, Germany

Fig. 1 Program of the Online URBIO Webinar “Urban Biodiversity and Design in Time of Pandemics”, 9 December 2021

Fig. 2 7th international URBIO conference “integrating biodiversity in urban planning and design processes” on the 28th-30th November 2022, UFZ Leipzig. (Source: Ignatieva et al. 2023)



countries and South Africa) concentrated on people’s attitudes and motivations during the COVID-19 pandemic towards urban home gardens and public spaces, private land contributes to urban biodiversity and ecosystem services, the role of urban blue and green infrastructure and influence on urban biodiversity and ecosystem services (Fig. 1). Then participants were asked to answer a questionnaire (described and analyzed in the next sections of this paper).

URBIO conference

The 7th Conference of URBIO-International Network Urban Biodiversity and Design: “Integrating Biodiversity in Urban Planning and Design Processes” on the 28th-30th November 2022 was hosted by Helmholtz Centre for Environmental Research (UFZ) in Leipzig (Germany) in close cooperation with Humboldt University of Berlin, the University of Western Australia, and the University of Missouri (Fig. 2). The conference attracted 122 participants from 24

countries. Eight sessions covered the themes of integration of biodiversity in urban planning, green infrastructure and landscape design projects to urban plants and wildlife biodiversity and mechanisms of increasing biodiversity in urban areas, protection, and conservation strategies (Ignatieva et al. 2023). Special sessions were dedicated to the discussion of case studies of Nature-Based Solutions and their multiple co-benefits linked to biodiversity aspects and methodological approaches to implementation of biodiversity in design and planning. Due to a very recent COVID-19 experience, an additional session “Challenges and opportunities of urban biodiversity (e.g., ongoing climate change, the impact of COVID-19 pandemics, other societal challenges)” was included as well.

Results

In the latest URBIO 2022 conference, we discussed actual research in urban biodiversity and identified the main future directions of the URBIO movement (Fig. 3). The leading

theme that attracted the biggest number of presenters and participants was the integration of biodiversity in urban planning, green infrastructure, and landscape design projects. Another popular theme was ecological restoration and urban wildlife and plant biodiversity. One particular direction that emerged recently and clearly pronounced at URBIO 2022 was urban biodiversity in times of climate change and post-pandemics. The last conference showed a strong interest in practical applications of urban biodiversity research in planning, design, and management practices at different scales (big scale of green infrastructure and ecological corridors, middle scale of urban parks and small scale of a private garden or street trees). The permanent and increasing interest of presenters in studying the biodiversity of urban areas, particularly plants and animals confirmed the tied connections of URBIO with the Convention on Biological Diversity. URBIO’s goal from the very beginning was the research and the protection of biodiversity in modified urban landscapes. One of the main URBIO’s directions is conducting transdisciplinary research on biodiversity by

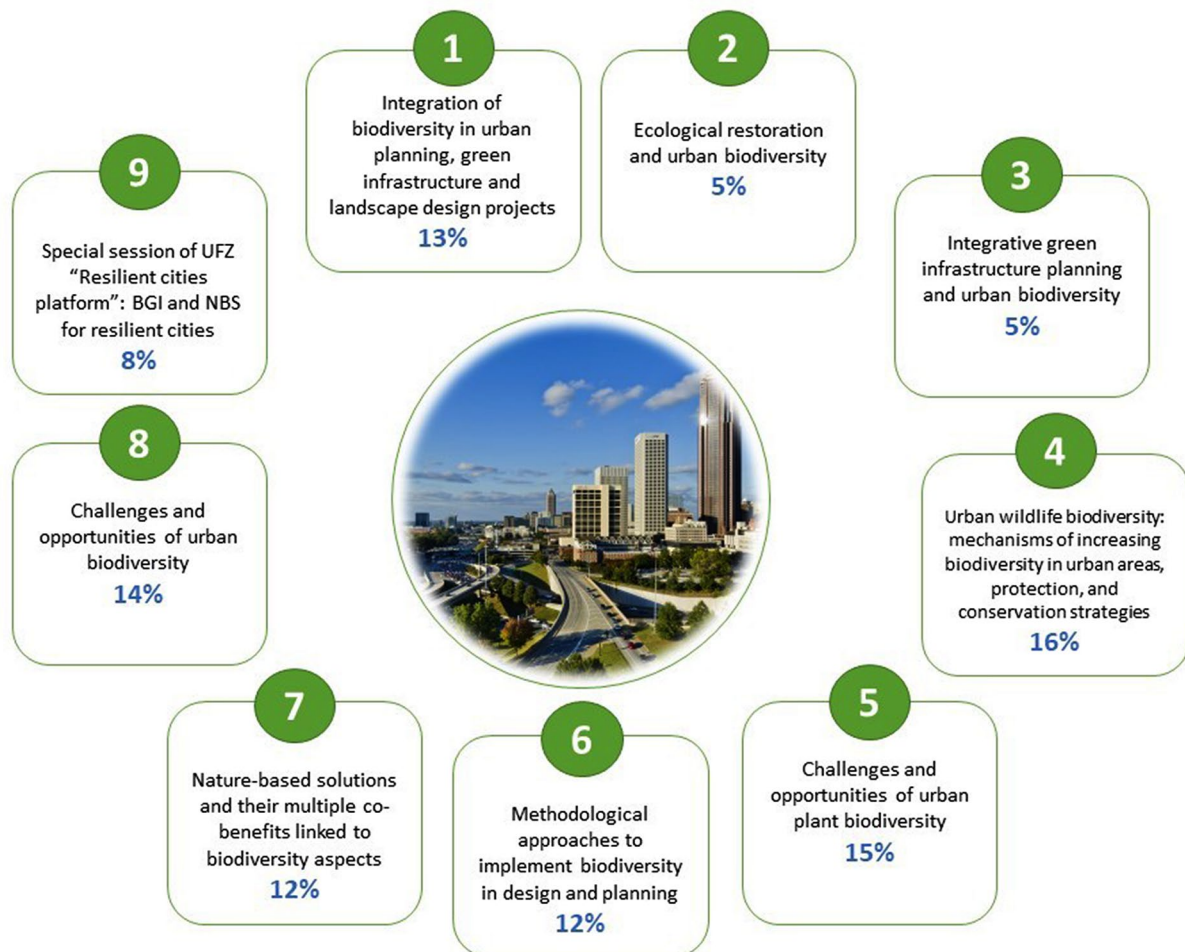


Fig. 3 Distribution of the main research topics/subjects presented during the 7th URBIO conference

Negative impact of COVID-19 pandemics and related restrictions was referred to the three main aspects (Fig. 7):

- closure of urban parks and less opportunity for the outdoor recreation (“no use of urban green spaces due to restrictions”, “poor maintenance /neglect of urban green space”, “less protection of UGS”, “less weed management”; “budget cuts for development”, “less recreation-based funding”);
- overuse of urban parks and open green spaces after lockdown and restrictions as well as related consequences (“more crowded UGS”, “pressure on parks”, “littering”);
- increased pressure on non-urban nature and wild animal damages due to less management (“more hunting”, “more fishing”, “more waste/garbage/plastic packaging”, “wild animal damages”, “environmental degradation”, “pollution by medical materials”, “water pollution”).

Some of the experts also mentioned that in general, the negative impact on biodiversity was not that much compared to impact on “...social and psychological wellbeing of people”.

The survey results allowed to reveal four most important/hottest topics of the research linked to COVID-19 pandemics and urban biodiversity in the local context (mentioned by 54 from 63 experts):

- 1) Investigation of biodiversity in new circumstances:
 - increasing biodiversity/plant communities because of decreasing human disturbance/pressure.
 - need for new methods for empirical research in urban ecology.
 - sustainable functions and quality of urban green spaces.
 - the observing of many bird species and the increase in enthusiasm of people towards nature.
- 2) Ecosystem services (EC) provided by biodiversity and green-blue infrastructure (GBI):
 - the role of urban GBI and biodiversity for coping with COVID-19.
 - value of urban green spaces for physical & mental health and social wellbeing.
 - home gardens and food production.
 - greater human-wildlife interactions, overall interaction with nature.
 - climate change and pollution in cities.
- 3) Urban planning and design of green spaces:



Fig. 6 Positive impact of the COVID-19 pandemic on urban biodiversity and the environment in the city of the current live / aspects which relate to “less” (e.g. decreased noise, traffic, pollution, anthropogenic pressure, etc.) (N=57)

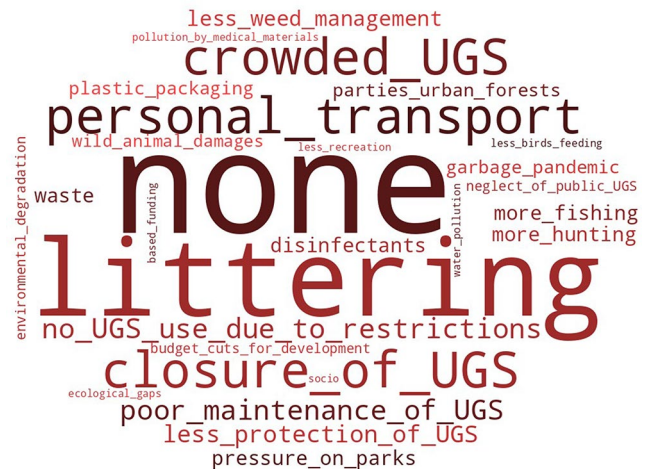


Fig. 7 Negative impact of the COVID-19 pandemic on urban biodiversity and the environment in the city where you currently live (N=63)

- urban land governance and lack of human and financial resources.
- accessibility and availability of GBI.
- post-pandemic landscape design and win-win for biodiversity and human wellbeing.
- co-creation: maintaining new urban biodiversity initiatives (local).
- redesign of urban green spaces to provide more opportunities for people interaction.
- management of biodiversity in cities.
- nature-based solutions in urban areas.
- changing management strategies for green areas.
- human-centric design.

4) New urban biodiversity initiatives and projects.

- maintaining new urban biodiversity initiatives, particularly local habitat restoration projects.
- decreased focus on urban green space development projects.
- co-governance.
- multi-city analysis on the impact of COVID-19 on citizen science.
- ESG (Environmental, Social, Governance) management, carbon-neutral activities of private companies.

In regard to the involvement in the certain field of research within urban biodiversity and design for the next years, the majority of experts mentioned the importance of rethinking strategies for urban planning and design (20.1%), biodiversity assessment (19.0%), research on sustainable practical design solutions to enable humans to live in balance with nature (15.8%), and developing new interdisciplinary programs to support urban biodiversity (15.8%) (Fig. 8).

Discussion

There are several other conferences on biodiversity that were held during and after the COVID 19 pandemic:

- The IPBES Bureau and Multidisciplinary Expert Panel (MEP) authorized a workshop on biodiversity and

pandemics that was held virtually on 27–31 July 2020 in accordance with the provisions on “Platform workshops” in support of Plenary-approved activities (focus on native biodiversity conservation).

- The 3rd SURE (Society for Urban Ecology) World Conference, 7–9 July 2021, under the topic “Cities as Socio-Ecological Systems” took place in Poznan, Poland. Organized as a hybrid event due to the current pandemic restrictions, over 300 participants online and onsite from 36 countries and 6 continents participated at the conference, with many sessions including sessions on ecosystem services of all ecosystem types – data, indicators, bundles, synergies and trade-offs, nature protection in urban areas, biodiversity in urban areas.
- A series of local ecological conferences such as Australian Ecological Society conference 2021 (online), with one session on urban ecology.
- The International Conference on Human-Wildlife Conflict and Coexistence took place from 30 March to 1 April 2023 in Oxford, UK. It was organised by the IUCN SSC Human-Wildlife Conflict & Coexistence Specialist Group, and co-hosted with the GEF-funded and World Bank-led Global Wildlife Program, and WildCRU of Oxford University.
- IUCN Webinar Series in October-November 2020: The last sprint to CBD COP15 – Webinar on how to achieve species goals and targets of the post-2020 global biodiversity framework, on the NBS and ESs in the post-2020 global biodiversity framework.

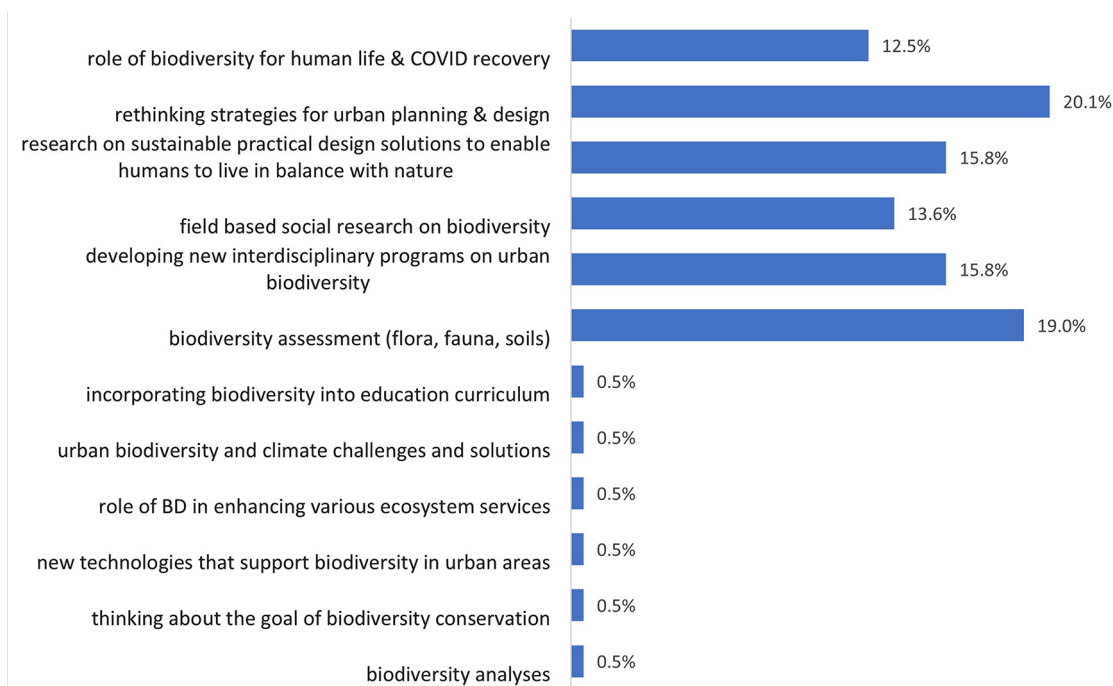


Fig. 8 Responses to the questions on the involvement of the expert into the certain field of research on urban biodiversity and design within the next years ($N=71$)

- A number of national online webinars related to the native biodiversity conservation was organized (e.g. on the impacts, challenges and opportunities for India's biodiversity research and conservation vis-à-vis COVID-19).

However, none of these conferences targeted specifically urban biodiversity and the character of designed green spaces during pandemic time.

There are some similarities concerning topics covered in the URBIO Webinar 2021 and the URBIO 2022 conference, but also several differences. Particularly, the main difference between URBIO conference 2022 and the 2021 URBIO Webinar from conferences mentioned above is the inter- and transdisciplinary approaches that reflect the unique nature of URBIO's movement – to implement theoretical and empirical data on urban biodiversity to urban planning, landscape design and landscape management practices. The conferences mentioned above mostly targeted first of all the native biodiversity conservation and protection measures. The closest event in the sense of research themes is the SURE Congress which provided a very wide range of studies related to urban environment. However, the URBIO has a unique straight-forward target for practical applications of traditional research on urban wildlife and urban vegetation and related socio-ecological aspects of biodiversity research to urban planning and design.

Research results presented and discussed within both URBIO 2021 and 2022 activities were aiming to explain why urban biodiversity is so important for human beings in times of the crises such as climate change and pandemics. Other studies (Da Schio et al. 2021; Grima et al. 2020; Lawler et al. 2021; Soga et al. 2021; Ugolini et al. 2020; UN Habitat 2021) also stated that the ongoing crisis has highlighted the crucial, potentially adaptable role of urban areas and particularly UGS in the post-pandemic recovery. Analysis of presentations at the conferences and the participants' answers to surveys revealed the importance of the classical primary research on plant and wildlife biodiversity and their conservation strategies in cities. This essential database is a tool that could help to understand and address the challenges causing loss of biodiversity and deterioration of ecosystems in cities. The research presented during the conferences demonstrated that the COVID-19 pandemic revealed new potentials and opportunities for improving biodiversity in cities (Dushkova et al. 2021). Case studies from the Global North and the Global South demonstrated the concrete pathways for the integration of biodiversity in urban planning and design processes and strategies (Ignatieva et al. 2023). The approaches proposed by the URBIO experts and conference participants for future URBIO research included:

- identifying and understanding the mechanisms of increasing biodiversity in urban areas, protection and conservation strategies in regard to urban plant and wildlife biodiversity (also mentioned in studies of Guerry et al. 2021; Lawler et al. 2021; IUCN, 2020; Rastandeh and Jarchow 2020);
- broadening the scope of wildlife biodiversity research by including different groups of organisms (similar to research of Corlett et al. 2020 and Egerer and Buchholtz 2021) who emphasized the need for transition towards a more comprehensive and inclusive approach to urban wildlife research);
- developing sustainable practical design solutions for better integration of biodiversity in urban planning, green infrastructure and landscape design projects (which corresponds with the conclusion of Ahmadpoor and Shahab 2021 and Kleinschroth and Kowarik 2020 on the importance of urban green spaces in planning and design);
- emphasizing the importance of local context and practices (also mentioned by McNeely 2021; Guerry et al. 2021);
- searching for new methodological approaches and technologies to implementing biodiversity in design and planning, including nature-based solutions and ecological design and their multiple co-benefits linked to addressing biodiversity loss and climate change (also mentioned in research by Lehmann 2021; Sharifi and Khavarian-Garmsir 2020; Giles-Corti et al. 2023 on the use of nature-based solutions to protect natural habitats and biodiversity and by Matasov et al. 2023 on the use of machine learning analysis of social media data to reveal new patterns in citizens' recreational use and activities to adapt the spatial structure of urban green spaces);
- developing new interdisciplinary programs on ecological restoration, for example returning biodiversity to the cities and related social aspects (such as projects described by Hinds et al. 2022; Leou et al. 2023);
- rethinking strategies for the management of urban green-blue infrastructure to increase biodiversity and human-positive perception, using new technology and innovative concepts (in line with the findings of Barton et al. 2020 and Pouso et al. 2021 on the importance of access to green space and the approaches for their better integration within the urban fabric).

Research results presented at the conference stressed the importance of incorporating a participatory approach/co-creation into studying biodiversity in cities (e.g., co-planning, co-design, co-implementation, and co-monitoring/co-evaluation with a variety of different stakeholders, including local residents) which is in line and even expanded CBD focus on cities. Such an approach which combines the sustainability concept with the concept of co-creation is actively used in research on the development and implementation of nature-based solutions and was demonstrated as successful in a variety of presentations

during the URBIO 2022 conference (Ignatieva et al. 2023). Other existing studies (e.g. Giles-Corti et al. 2023; Sharifi and Khavarian-Garmsir 2020) also highlighted additional benefits for biodiversity, the protection of wildlife corridors, climate change adaptation, and resilience to urban heat.

Analysis of two URBIO conferences, participants' responses on challenges for the future, and the URBIO declaration 2022 can be summarized as an action plan that includes:

- Encouraging interdisciplinary and transdisciplinary research on urban biodiversity by involving urban citizens and decision-makers.
- Increasing the role of the next generation of researchers and planners who will reinforce URBIO's involvement in the activities of the Convention on Biological Diversity.
- Recognizing urban biodiversity as a complex and specific phenomenon of urban nature that includes native and non-native biota but acknowledging the detrimental effect of invasive alien species.
- Urgent research of all components of urban biodiversity, especially in the Global South (along the entire socio-economic gradient) and other fast-growing regions as well as in countries located in biodiversity hotspots.
- Increasing the role of education: to expand the incorporation of key concepts from urban ecology, planning, ecological design, and the activities of the Convention on Biological Diversity's work in cities into the university curriculum (natural sciences as well as design and planning programs).
- Reinforcing integration of biodiversity and design using innovative concepts such as ecological planning, ecological design, nature-based solutions, and green-blue infrastructure.
- Reinforcing collaboration between urban ecologists, planners, geographers, landscape architects, sociologists, and artists. Reach out/supply scientific input to implement platforms such as the GEF-8 (The Global Environment Facility) Cities program (Moving Toward an Equitable, Nature-Positive, Carbon-Neutral, and Pollution-Free World), the WB's (World Bank) Cities4Biodiversity, the ICLEI (Local Governments for Sustainability).

Following the results of the survey and the analysis of the URBIO Webinar 2021 and URBIO 2022 conferences, the research theme for the next 2024 URBIO conference has been decided to focus on urban biodiversity and design for local communities. Pandemic and post-pandemic times revealed the future research directions for URBIO activities such as returning native biodiversity in urban public and private spaces;

community approaches to nature conservation and nature-based solutions in urban areas; interdisciplinary research projects for communities and development of education in urban biodiversity.

Conclusion

This paper presented the results of research on urban biodiversity and design in a time of pandemic and post-pandemic based on the surveys among the URBIO experts and the related URBIO events. The presentations of the URBIO conference and the webinar talks were analyzed using a thematic approach. We identified the unique target of the URBIO network – the implementation of research into practice. For example, traditional research included urban wildlife and urban vegetation, related socio-ecological aspects of biodiversity research, and their implementation in urban planning and design. Studies presented during the URBIO events and responses of URBIO experts to the surveys underlined new potentials and opportunities for improving biodiversity and design in cities by demonstrating the concrete pathways for integration of biodiversity in urban planning and design processes and strategies. They also include various human-nature interactions and innovative strategies aimed at fostering positive outcomes for both people and urban biodiversity. The areas for future research on urban biodiversity and design are provided based on the outcomes from the URBIO webinar (2021) and conference (2022) as well as results from a questionnaire survey among URBIO experts. The areas are the following: investigating biodiversity in urban areas and implementing conservation strategies; expanding wildlife biodiversity research to include various organisms; developing sustainable design solutions for urban planning and green infrastructure projects; considering local context and community involvement; exploring new methods and technologies for biodiversity implementation; establishing inter- and transdisciplinary programs for ecological restoration in cities; rethinking urban green-blue infrastructure management for biodiversity and positive human perception; utilizing new technology and innovative concepts and incorporating participatory approaches in biodiversity studies, such as co-planning, co-design, and co-implementation with various stakeholders. URBIO provides global perspectives on urban biodiversity with insights from research and practice.

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Declarations

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References

Ahmadpoor N, Shahab S (2021) Urban form: realising the value of green space: a planners’ perspective on the COVID-19 pandemic. *Town Plan Rev* 92:49–55. <https://doi.org/10.3828/tp.2020.3>

- Barton D, Haase D, Mascarenhas A, Langemeyer J, Baro F, Kennedy C, Grabowski Z, McPhearson T, Krog NH, Venter Z et al (2020) Enabling Access to Greenspace during the COVID-19 Pandemic—Perspectives from Five Cities. *The Nature of Cities*. 4 May 2020. <https://www.thenatureofcities.com/2020/05/04/enabling-access-to-greenspace-during-the-covid-19-pandemic-perspectives-from-five-cities/>. Accessed 8 February 2022
- Chan L, Hillel O, Werner P, Holman N, Coetzee I, Galt R, Elmqvist T (2020) Handbook on the Singapore Index on cities’ Biodiversity (also known as the City Biodiversity Index). Montreal: Secretariat of the convention on Biological Diversity and Singapore. National Parks Board, Singapore
- Corlett RT, Primack RB, Devictor V, Maas B, Goswami VR, Bates AE et al (2020) Impacts of the coronavirus pandemic on biodiversity conservation. *Biol Conserv* 246:108571. <https://doi.org/10.1016/j.biocon.2020.108571>
- Da Schio N, Philips A, Franssen K et al (2021) The impact of the COVID-19 pandemic on the use of and attitudes towards urban forests and green spaces: exploring the instigators of change in Belgium. *Urban Urban Green* 65:127305. <https://doi.org/10.1016/j.ufug.2021.127305>
- Drisko J, Maschi T (2016) Content analysis. Oxford University Press, Oxford. <https://doi.org/10.1093/acprof:oso/9780190215491.001.0001>
- Dushkova D, Ignatieva M, Hughes M, Konstantinova A, Vasenev V, Dovletyarova E (2021) Human dimensions of urban blue and green infrastructure during a pandemic. Case study of Moscow (Russia) and Perth (Australia). *Sustainability* 13(8):4148. <https://doi.org/10.3390/su13084148>
- Dushkova D, Ignatieva M, Konstantinova A, Vasenev V, Dovletyarova E, Dvornikov Y (2022) Human-Nature Interactions during and after the COVID-19 Pandemic in Moscow, Russia: Exploring the Role of Contact with Nature and Main Lessons from the City Responses. *Land* 11:822. <https://doi.org/10.3390/land11060822>.
- Egerer M, Buchholz S (2021) Reframing urban wildlife to promote inclusive conservation science and practice. *Biodivers Conserv* 30:2255–2266. <https://doi.org/10.1007/s10531-021-02182-y>
- Elmqvist T, Fragkias M, Goodness J, Güneralp B, Marcotullio PJ, McDonald RI, Parnell S, Schewenius M, Sendstad M, Seto KC, Wilkinson C (eds.) (2013) Urbanization, Biodiversity and Ecosystem Services: Challenges and Opportunities: A Global Assessment. Springer, New York open access 755.
- Finnsön PT (2020) COVID-19 Crisis Highlights the Need for Accessible and Productive Urban Green Spaces. *Nordregio Magazine* 2020. Issue Postpandemic Regional Development. <https://nordregio.org/nordregio-magazine/issues/post-pandemic-regional-development/covid19-crisis-highlights-the-need-for-accessible-and-productive-urban-green-spaces/>. Accessed 15 June 2023
- Giles-Corti B, Foster S, Lynch B et al (2023) What are the lessons from COVID-19 for creating healthy, sustainable, resilient future cities? *Urban Sustain* 3:29. <https://doi.org/10.1038/s42949-023-00107-y>
- Graziano T (2021) Smart technologies, back-to-the-village rhetoric, and Tactical Urbanism: Post-COVID planning scenarios in Italy. *Int J E-Plan Res (IJEPR)* 10:80–93
- Grima N, Corcoran W, Hill-James C, Langton B, Sommer H, Fisher B (2020) The importance of urban natural areas and urban ecosystem services during the COVID-19 pandemic. *PLoS ONE* 15:e0243344. <https://doi.org/10.1371/journal.pone.0243344>
- Guerry AD, Smith JR, Lonsdorf E, Daily GC, Wang X, Yuna Chun (2021) Urban Nature and Biodiversity for Cities. Policy briefing. Global platform for sustainable cities, World Bank. World Bank, Washington, DC

- Gundimeda H (ed) (2012): URBIO 2012 - Urban Biodiversity and Climate Change: Adaptation and Mitigation - Book of Abstracts. - Mumbai, Indian Institute of Technology Bombay: 150 pages
- Hinds KA, Platz MC, Zarger R, Arias ME (2022) Engaging in Interdisciplinary Coastal Research during a pandemic. *Hum Organ* 81(3):271–279. <https://doi.org/10.17730/1938-3525-81.3.271>
- Ignatieva M, Dushkova D, Nilon C, Haase D, Knapp S, Bittorf N (2023) Integrating biodiversity in urban planning and design processes. Book of abstracts of the 7th International Conference of the network URBIO – Urban Biodiversity & Design. 28–30 November 2022. Helmholtz Centre for Environmental Research – UFZ, Leipzig, Germany. <https://doi.org/10.57699/hd4s-e705>
- Imanishi J, Hon J (eds) (2010): Proceedings of the 2nd International Conference of Urban Biodiversity and Design (URBIO2010) Nagoya, Japan, May 18–22, 2010. - Kyoto, The URBIO2010 Organizing Committee: 398 pages
- IUCN - International Union for Conservation of Nature (2020) Conserving nature in a time of crisis: Protected areas and COVID-19. Available online at: <https://www.iucn.org/news/world-commission-protected-areas/202005/conserving-nature-a-time-crisis-protected-areas-and-covid-19> (accessed February 28, 2024)
- Kim N (ed) (2014): Proceedings of the 4th international conference of urban biodiversity and design (URBIO 2014) - Cities and Water - Conservation, Restoration and Biodiversity. - Seoul, The Korean Society of Environmental Restoration Technology (KOSERT): 388 pages
- Kleinschroth F, Kowarik I (2020) COVID-19 crisis demonstrates the urgent need for urban greenspaces. *Front Ecol Environ* 18:318–319. <https://doi.org/10.1002/fee.2230>
- Lawler OK et al (2021) The COVID-19 pandemic is intricately linked to biodiversity loss and ecosystem health. *Lancet Planet Health* 5:e840–e850
- Lehmann S (2021) Growing Biodiverse Urban futures: renaturalization and rewilding as strategies to strengthen Urban Resilience. *Sustainability* 13:2932. <https://doi.org/10.3390/su13052932>
- Leou M, Goicoechea T, Kogut B (2023) Community Garden as a Context for Civic Ecology: a Multidisciplinary Project in Restoration and Environmental Education. *Cities Environ (CATE)* 16(2):1. <https://doi.org/10.15365/cate.2023.160201>
- Matasov V, Vasenev V, Matasov D, Dvornikov Yu, Filyushkina A, Bubalo M, Nakhaev M, Konstantinova A (2023) COVID-19 pandemic changes the recreational use of Moscow parks in space and time: outcomes from crowd-sourcing and machine learning. *Urban Forestry Urban Green* 83:127911. <https://doi.org/10.1016/j.ufug.2023.127911>
- McNaught C, Paul L (2010) Using Wordle as a supplementary Research Tool. *Qualitative Rep* 15(3):630–643. <http://www.nova.edu/ssss/QR/QR15-3/mcnaught.pdf>
- McNeely JA (2021) Nature and COVID-19: the pandemic, the environment, and the way ahead. *Ambio* 50:767–781. <https://doi.org/10.1007/s13280-020-01447-0>
- Morand S, Lajaunie C (2021) Biodiversity and COVID-19: a report and a long road ahead to avoid another pandemic. *One Earth* 4(7):920–923. <https://doi.org/10.1016/j.oneear.2021.06.007>
- Mouratidis K (2021) How COVID-19 reshaped quality of life in cities: a synthesis and implications for urban planning. *Land Pol* 111:105772. <https://doi.org/10.1016/j.landusepol.2021.105772>
- Müller N, Kümmerling M (eds) (2013): Proceedings URBIO Workshop 2013 – Global Research Agenda for Urban Biodiversity, Ecosystem Services & Design. - Erfurt, URBIO Headquarters, University of Applied Sciences Erfurt: 26 pages. (3,3 MB)
- Müller N, Elsner K (2016) Proceedings URBIO Index Workshop 2016. University of Applied Sciences Erfurt, Erfurt. <https://doi.org/10.13140/RG.2.2.14351.97448>
- Müller N, Kamada M (2011) URBIO: an introduction to the International Network in Urban Biodiversity and Design. *Landsc Ecol Eng* 7:1–8. <https://doi.org/10.1007/s11355-010-0139-7>
- Müller N, Werner P (2024) A review on the work of urban biodiversity networks in Germany – from national to international activities. *Urban Ecosystems* (in prep.)
- Müller N, Knight D, Werner P (2008) eds *Urban Biodiversity and Design - implementing the convention on Biological diversity in towns and cities - book of abstracts*. BfN Skripten 229-1 265–pages
- Müller N, Werner P, Kelcey JK (2010) *Urban Biodiversity and Design*. Hoboken N. J. Wiley-Blackwell. <https://doi.org/10.1002/9781444318654>
- Oke C, Bekessy SA, Frantzeskaki N et al (2021) Cities should respond to the biodiversity extinction crisis. *Urban Sustain* 1:11. <https://doi.org/10.1038/s42949-020-00010-w>
- Pouso S, Borja A, Fleming LE, Gómez-Baggethun E, White MP, Uyarra MC (2021) Contact with blue-green spaces during the COVID-19 pandemic lockdown beneficial for mental health. *Sci Total Environ* 756:143984. <https://doi.org/10.1016/j.scitotenv.2020.143984>
- Ramvilas G, Dhyani S, Kumar B, Sinha N, Raghavan R, Selvaraj G, Divakar N, Anoop VK, Shalu K, Sinha A, Kulkarni A, Das S, Molur S (2021) Insights on COVID-19 impacts, challenges and opportunities for India's biodiversity research: from complexity to building adaptations. *Biol Conserv* 255:109003. <https://doi.org/10.1016/j.biocon.2021.109003>
- Rastandeh A, Jarchow M (2020) Urbanization and biodiversity loss in the post-COVID-19 era: complex challenges and possible solutions. *Cities Health* 1–4. <https://doi.org/10.1080/23748834.2020.1788322>
- Schultz M, Elmquist T (2014) *Cities and Biodiversity Outlook*. Stockholm Resilience Centre Brief. https://www.stockholmresilience.org/download/18.10119fc11455d3c557d3dc38/1459560235045/SRC_brief_1_CBO.pdf. Accessed 25 July 2023)
- Sharifi A, Khavarian-Garmsir AR (2020) The COVID-19 pandemic: impacts on cities and major lessons for urban planning, design, and management. *Sci Total Environ* 749:142391. <https://doi.org/10.1016/j.scitotenv.2020.142391>
- Slater SJ, Christiana RW, Gustat J (2020) Recommendations for keeping Parks and Green Space Accessible for Mental and Physical Health during COVID-19 and other pandemics. *Prev Chronic Dis* 17:200204. <https://doi.org/10.5888/pcd17.200204>
- Soga M, Evans MJ, Cox DTC, Gaston KJ (2021) Impacts of the COVID-19 pandemic on human–nature interactions: pathways, evidence and implications. *People Nat* 3:518–527. <https://doi.org/10.1002/pan3.10201>
- Stemler S (2001) An overview of content analysis. *Practical Assess Res Evaluation* 7:17. <https://doi.org/10.7275/z6fm-2e34>
- Uchiyama Y, Kohsaka R (2020) Access and Use of Green areas during the COVID-19 pandemic: Green Infrastructure Management in the New Normal. *Sustainability* 12(23):9842. <https://doi.org/10.3390/su12239842>
- Ugolini F, Massetti L, Calaza-Martinez P, Cariñanos P, Dobbs C, Ostoic SK, Marin AM, Pearlmutter D, Saaroni H, Šaulienė I et al (2020) Effects of the COVID-19 pandemic on the use and perceptions of urban green space: an international exploratory study. *Urban Urban Green* 56:126888. <https://doi.org/10.1016/j.ufug.2020.126888>
- UN Habitat (2021) *Cities and pandemics: towards a more just, Green and Healthy Future*. In: Tuts R, Knudsen C, Moreno E, Williams C, Khor N (eds) *United Nations Human Settlements Programme. UN-Habitat*: Nairobi, Kenya

Zhang X, Zhang Y, Zhai J (2021) Home Garden with Eco-healing functions benefiting Mental Health and Biodiversity during and after the COVID-19 pandemic: a scoping review. *Front Public Health* 9:740187. <https://doi.org/10.3389/fpubh.2021.740187>

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