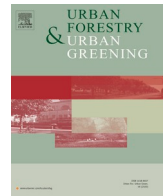




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Review article

Exploring the restorative capacity of urban green spaces and their biodiversity through an adapted One Health approach: A scoping review

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ABSTRACT

The One Health framework was proposed by the World Health Organisation to explore human, animal, and environmental health interfaces using a holistic and interdisciplinary approach. Yet, the application of this framework to study urban green spaces has been poorly explored in the literature. As the amount of evidence on urban green spaces for citizens' health and well-being is increasing, the use of a One Health framework may contribute to understanding urban green spaces from a comprehensive, interrelated and multidisciplinary perspective that comprises people, biodiversity and the urban environment. To explore this gap in the literature, this study presents a scoping review, which analysed 50 studies through an adapted version of the One Health framework, using the interfaces between human mental health, urban green spaces and urban biodiversity as analytical lenses. The review yielded three main findings: the restorative capacity of urban green spaces as a critical aspect of overall human health, the values of restorative capacity from having contact with urban biodiversity, and how ecological knowledge promotes biodiversity conservation in cities. This paper also discusses opportunities to continue expanding One Health by engaging with interdisciplinary discussions and cross-sectoral collaborations. We conclude with an invitation to explore and extend the One Health framework with respect to augmenting urban green spaces as restorative settings and valuing their capacity to contribute to public awareness of biodiversity and, in turn, contribute to improving human and environmental health in cities.

1. Introduction

Urbanization is a critical global issue that impacts biodiversity conservation, human health and well-being, reducing opportunities for human contact with nature in urban settings (Hartig & Staats, 2006; Cox et al., 2018; Elmqvist et al., 2021). This lack of interaction is causing disconnection with nature and urban wildlife in urban settings (Soga and Gaston, 2016; Beery et al., 2023). Likewise, decreasing nature experiences impacts citizens' physical health and psychological well-being

(Srivastava, 2009), having a reverse impact on psychological restoration, subjective well-being and opportunities for recreation (Hartig et al., 2014; Shanahan et al., 2016; Soga et al., 2017). Policymakers are therefore calling for reliable and sustainable solutions to support biodiversity and improve the health and well-being of urban dwellers (European Union, 2019; UNDP, 2023). Urban green spaces (UGS) are increasingly in focus as a multi-functional solution to increasing nature experience in cities (Beute et al., 2020; WHO, 2023).

In the last decades, a large body of empirical and theoretical

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literature has demonstrated the multiple benefits associated with UGS in supporting urban biodiversity habitats (Goddard et al., 2010; Loh, 2021), psychological connection through promoting contact with nature (Barragan-Jason et al., 2023), enhancing physical and mental health associated to their recreational, aesthetic merits and biological richness and qualities (Barton & Rogerson, 2017; Fisher et al., 2017; Marselle et al., 2021), and contributing to socio-economic and health equality by enhancing accessibility and safety (Escobedo et al., 2015). Most of these studies have been focused on what is known as *formal green spaces* (Rupprecht et al., 2015; Pietrzyk-Kaszyńska et al., 2017), referring to natural and semi-natural spaces with a degree of human management and intervention (Taylor et al., 2020; Krapez et al., 2021), such as urban parks (Paliwoda et al., 2017) or community and private gardens (Thompson, 2018; Hanson et al., 2021). These types of UGS are defined in the literature as “well-recognized, clearly demarcated, managed and maintained forms of vegetation assemblages, namely parks, allotment gardens, botanical gardens, peri-urban areas, urban forests and cemeteries” (Pietrzyk-Kaszyńska et al. 2017, p. 86). This definition encompasses public, accessible and highly maintained environments to relatively natural landscapes with varying levels and types of naturalness, grass, trees, shrubs or other native vegetation (Lachowycz & Jones, 2013; de Haas et al., 2021; Atiqul Haq et al., 2021). Urban green landscapes may also include rivers, lakes, ponds and sea-coasts within cities. They are known in the literature as green and blue spaces, and they were also considered in this review due to their increasing relevance to citizens’ mental health restoration as they provide opportunities to have contact with nature and stimulate calmness, healing and physical and mental health restoration (Smith et al., 2021; WHO, 2023).

Although many studies have looked independently at the relationship between UGS and mental health (WHO, 2016; WHO, 2022) and the importance of UGS for biodiversity support (Łopucki & Kiersztyn, 2015; Threlfall et al., 2017), few studies have taken a system-thinking approach, which intends to holistically understand complexity by considering interactions, behaviours and interlinked influences of the system across multiple scales and dimensions (Rigby et al., 2022), to examining UGS (Cristiano & Zilio, 2021 & Salvia et al., 2022). An example of a system-thinking approach, with the potential of studying UGS from a nexus between human health, biodiversity and the environment, is the One Health framework, which consists originally of three interfaced dimensions, namely environmental health, animal health and human health (WHO, 2017).

The One Health framework has been principally proposed and used for the study of zoonotic diseases and human physical health outcomes that require a broader understanding of human-animal contact (Ghai et al., 2022). It advocates that “complex health and ecological challenges should be addressed through a holistic, interdisciplinary and system-thinking approach that recognizes the interconnections between the health of humans, animals and the environment” (Felappi et al., 2020, p.2). Despite its potential to study human health from a holistic and multi-functional perspective, this framework has been poorly used and applied for the study of complex socio-ecological systems such as UGS (Felappi et al., 2020). This is important because the application of a One Health framework may help to uncover the linkages between human mental health, biodiversity and UGS from an integral and interdisciplinary perspective that sheds light on the contributions, challenges and opportunities when designing and planning healthy UGS for citizens, the environment and its biodiversity.

This paper reports the process and results of a scoping review that aimed to explore and map what has been written about UGS in relation to human mental health and urban biodiversity, through a One Health approach. However, given that cities are complex social-ecological systems (Bonilla-Bedoya et al., 2020), in this scoping review, we adapted the One Health framework to reflect these complex social-ecological dynamics concerning human, environmental and biodiversity health. The adapted version of the One Health framework proposes nuanced interfaces between human mental health and urban

biodiversity in the context of UGS as an analytical framework. Moreover, it highlights the importance of uncovering the interfaced dimensions from a perspective that comprises human-biodiversity-environment-health interactions in urban settings. The results and discussions show the main emerging themes, trends and gaps in the literature. In addition, based on the findings of this review, this paper discusses the importance of conceptualising One Health in ways that integrate an interdisciplinary and cross-sectional dialogue. This complements this framework by engaging with relevant methodologies and discussions that contribute to conceiving green spaces and their planning in cities from an interrelated, inclusive and multidisciplinary perspective. We offer several insights on how the One Health approach can be expanded to broaden our understanding of the notion of *health* that includes and explores in-depth the complex socio-ecological and health relationships between humans, animals, plants, living beings and the environment in the UGS context. The findings and discussions presented here will be useful for urban planners and researchers interested in assessing and designing UGS from a One Health approach that invites to conceive UGS and health from an inclusive, interdisciplinary and interrelated perspective.

1.1. The One Health framework: approaches, adaptations and gaps

The One Health framework initially proposes the interface between human health, environmental health and animal health, framing a holistic view in which human health and well-being are interrelated to the health of animals and the health of the environment (Mackenzie and Jeggo, 2019; Hoffmann et al., 2022) (Fig. 1). This framework is designed to study the notion of health from an integrated and interdisciplinary perspective (WHO, 2017), including principally the involvement of veterinary and medical sectors to prevent, predict, detect and respond to emerging diseases and global threats resulting from human-animal contact such as zoonotic diseases (WHO, 2017; Andrivon et al., 2022; Horefti, 2023).

In the last decades, the discussion around the One Health framework has opened the opportunity to bring new perspectives, dimensions and interdisciplinary approaches into this framework. For instance, Andrivon et al. (2022) proposed the inclusion of Plant Health as one of the pillars of this integrative concept, highlighting synergies between plant health with the other dimensions of One Health (Andrivon et al., 2022). This led to extending this framework towards an interdisciplinary collaboration with agricultural sciences and opening research on food security and food systems through a One Health perspective (Hoffmann et al., 2022). Moreover, environmental sectors have recently engaged with this framework in order to explore further the dimension of environmental health, which has been overlooked and poorly discussed and

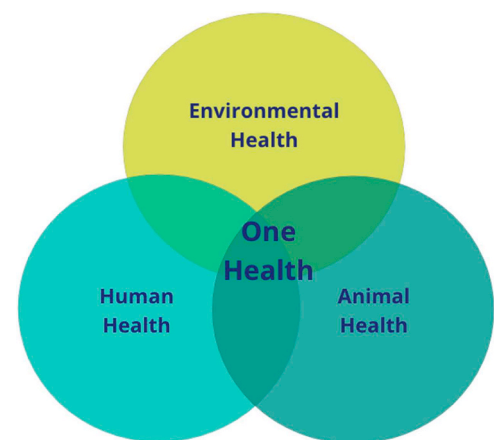


Fig. 1. Original One Health framework as depicted by the World Health Organization, 2017 and One Health Trust, 2022.

defined in this framework (Taing et al., 2022).

Similarly, and despite the limited engagement of One Health with social sciences (Van Patter et al., 2023), there has been an emerging discussion with humanities and anthropology around integrating a more-than-human lens into One Health, intended to research in-depth human-nature-health relationships by using qualitative methods and theories from the social sciences for uncovering relationalities and socialisations (Lainé and Morand, 2020), and encouraging close collaborations with local communities and their local knowledge (Quinlan & Quinlan, 2016). This more-than-human lens is thought to contribute to challenging human-centred paradigms permeated in the One Health framework, as it claims the need to not only focus on human health as the ultimate outcome but to recognise that human health, biodiversity and the environment are intrinsically linked (Lainé and Morand, 2020).

These current debates and approaches towards One Health show that this framework is under current discussions and adaptations. This poses, therefore, new opportunities, challenges and potentials for applying this framework for the research of relevant and global health issues that require a holistic, interdisciplinary and integral perspective. This points to the need to include new dimensions, definitions and health contexts in relation to One Health.

In the context of urban greening, which represents an opportunity to explore the manifold benefits and contributions of urban nature for human health, animal health and environmental health, this framework has been poorly explored. To our knowledge, only one previous review studied urban green infrastructure (UGI), which comprises interconnected and multifunctional networks of natural, semi-natural and artificial urban green spaces, including parks, private gardens, living roofs and street trees (European Environment Agency (EEA), 2023), through a One Health lens. This review compiled and quantified UGI characteristics that impact mental health and animal health by identifying potential synergies and trade-offs between these two dimensions (Felappi et al., 2020). Yet, this study focuses mainly on quantifying UGI qualities rather than unpacking and discussing the different dimensions and relationalities derived from the interface of animal health and human mental health in UGI. This evidences that there is still the need and opportunity to continue adapting and using a One Health approach for the assessment and research of green spaces in urban settings in the

light of the One Health framework and from a qualitative and comprehensive analysis.

With this gap in knowledge and inspired by the different approaches and opportunities to use this framework in the urban greening context, we adapted a One Health framework to review and assess scientific literature on UGS from the nexus between urban biodiversity and human mental health. This adapted One Health approach contributes to uncovering and analysing from a comprehensive, interdisciplinary, qualitative and system-thinking approach the multiple interrelationships, definitions and perspectives derived from the interface between biodiversity, human health and environmental health in the context of UGS.

1.2. Adapted One Health approach for UGS

For the adaptation of the One Health framework for the assessment of UGS, we draw first on the question of how UGS can be studied in light of the interface between human mental health and urban biodiversity. For this purpose, we aimed for a socio-ecological-health approach that included the multiple and complex interactions between and across human mental health, biological diversity and different types of UGS in cities. This resulted in our adapted One Health framework that counts with three interfaced dimensions: human mental health, urban biodiversity and environmental health. These three dimensions are interfaced in the context of UGS (Fig. 2).

In our adaptation, we extended the dimension of animal health towards urban biodiversity to reflect the biological and ecological diversity that inhabits and interacts in UGS, including animal and plant species and the role of UGS in supporting and protecting urban biodiversity (See Box 1. Urban biodiversity dimension). For the dimension of human health, we focused on human mental health, drawing upon the definition of *human health* and *human mental health* proposed by the World Health Organization (See Box 1. Human mental health dimension). These definitions gave insights into understanding human mental health in the UGS context as an individual and social experience associated with different aspects of human health and well-being, such as mental health restoration, psychological and physical connection to nature, and subjective well-being (See Box 1. Human mental health

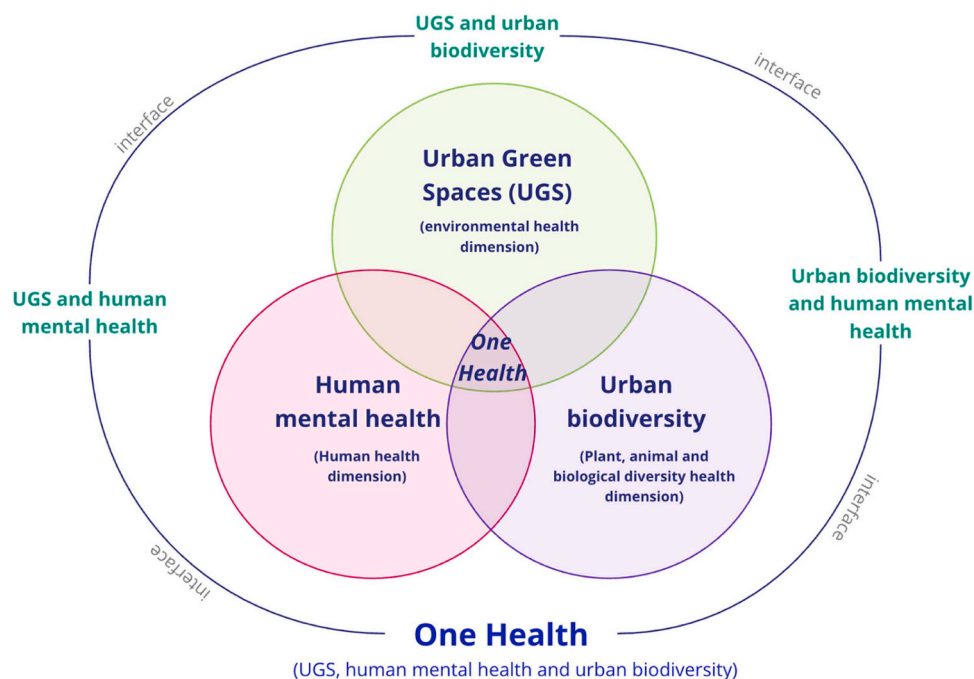


Fig. 2. Adapted One Health framework with its dimensions and interfaces identified, modified and depicted from the reviewed literature and the original One Health framework.

dimension).

For the environmental health dimension, we draw on the definition of UGS proposed by Pietrzyk-Kaszyńska et al. (2017) and WHO (2023), stating that UGS are natural features within urban environments that are well-recognized, clearly demarcated and with maintained forms of vegetation assemblages, including urban parks, allotment gardens, botanical gardens, peri-urban areas, urban forests, blue and green coastal areas and cemeteries (See Box 1. Environmental health dimension). We complemented this definition under the idea that the “state and quality of the environment has a significant impact on the biotic and abiotic components of the environment, thus essential for health and human living” (Pona et al., 2021, P. 1). Based on this, we integrated biophysical qualities such as levels of maintenance, greenery, biodiversity richness, naturalness or water characteristics (e.g. lakes, ponds, sea coastal areas) in the definition and evaluation of UGS in relation to human mental health and urban biodiversity (See Box 1. Environmental health dimension).

Upon these three adapted dimensions and their definitions, we identified the different interfaces and emerging themes when using this adapted One Health approach that comprises the interrelationships between human mental health, urban biodiversity and environmental health in the context of UGS (See Fig. 2 and Box 1).

2. Materials and methods

This qualitative scoping review followed the protocol outlined in the PRISMA guidelines (Moher et al., 2009). This method proceeds from a “clearly formulated question that uses systematic and explicit methods to identify, select and critically appraise relevant research, and to collect and analyse data from the studies included in the review” (Moher et al., 2009, p. 1). In our case, the main research question investigated how UGS is interfaced with human mental health and urban biodiversity and how these interfaces can be depicted and uncovered from a comprehensive One Health approach. This method was chosen because it facilitates mapping the body of literature, clarifies key concepts and definitions, and helps to identify and analyse knowledge gaps (Arksey & O’Malley, 2005).

The search strategy focused on the intersection of three main dimensions: green spaces, human mental health, and biodiversity in the urban context. Through this adaptation, it was possible to explore UGS as complex socio-ecological systems (Bonilla-Bedoya et al., 2020), opening the possibility to understanding that these spaces are composed by multiple living beings, including plants and animals that provide ecological benefits and contribute to ecosystem and human health (Wood & Esaian, 2020), and focusing mainly on one aspect of human health, human mental health (Fig. 2). The search was carried out in three databases: Scopus, Web of Science, and Science Direct (Elsevier). We chose these databases as they contain comprehensive and peer-reviewed scientific literature on a global scale, covering updated

Table 1
Search keywords and affiliated One Health dimensions.

Proposed One Health Dimension	Keywords
Environmental dimension (Urban green space)	(“green space” OR “landscape” OR “park”) AND
Mental health and well-being dimension	(“Mental health” OR “well-being” OR “psychological health” OR “happiness” OR “fear” OR “life satisfaction” OR “mental restoration” OR “stress recovery” OR “restoration” OR “restorative” OR “psychological” OR “mental illness” OR “Subjective well-being” OR “One Health” OR “Health”) AND
Wildlife and biodiversity dimension	(“Wildlife” OR “biodiversity”) AND
Urban setting (delimit searching on urban setting)	(Urban OR City)

and interdisciplinary evidence for our analysis. Keywords and similar terms associated with each dimension comprised the searching string (See Table 1). We used both generic and specific terms to capture all dimensions, and we drew our keywords selection from previous systematic reviews on urban green spaces and mental health (See Felappi et al., 2020; Beute et al., 2020).

In the search, the terms were included in either title or abstract. The search focused on papers published in peer-reviewed journals and book chapters that evidenced relevant contributions of UGS in relation to mental health and biodiversity. There was no restriction regarding geographic location, but we limited the searches to the period from January 2012 to September 2022. Establishing 2012 as the lower limit for our search allowed us to recognise that One Health is an emergent field consolidated in the last decades (WHO, 2017). However, the underlying concepts of interconnectedness between human, animal and environmental health have been explored for much longer in the epidemiology, veterinary and ecological fields (See: Hinchliffe, 2015; Horefti, 2023). With this timeframe, we aimed to identify and analyse trends and advancements in UGS research, as well as assess how the scientific literature has recognised the importance of UGS at the interface of human, biodiversity, and environmental health in the recent decade. Our search also included literature published before and after the COVID-19 pandemic, a global health crisis that significantly impacted our relationship with UGS (Davies and Sanesi, 2022).

Scientific literature published after the search date was included in the discussion. In order to verify the literature coverage, we used a snowballing process in the second step by reviewing the reference list of the selected articles and including relevant studies to this research. These studies were assessed and discussed with the co-authors to ensure they aligned with the selection and screening criteria (See Fig. 3. Step 3). Due to the large number of results, grey literature was not included.

2.1. Eligibility and selection criteria

Records were initially selected based on the screening of titles and abstracts. Records presenting at least one mental health outcome (e.g., psychological benefits or mental health restoration contributions) or one urban biodiversity outcome (e.g., evidence on biodiversity conservation or biodiversity support) were selected. Only papers and contributions in English were included, though it can be recognised that there may be a wider literature on this topic in other languages. Studies that reported socio-cultural and qualitative approaches towards UGS and urban biodiversity, such as citizens’ perceptions, local knowledge, preferences and aesthetics were also included. Likewise, we considered records with different target groups such as adults, children, elderly and vulnerable populations. This review included different types of UGS, such as public and accessible urban parks, allotment gardens, botanical gardens, peri-urban areas, urban forests and cemeteries. Papers on UGS with green and blue space characteristics, such as sea coastal areas and lakes (WHO, 2023), were also included as they yield relevant evidence on human health and urban biodiversity outcomes. Private green spaces, sport grounds, and rural and agricultural areas were excluded. Articles were excluded at this stage if they were incompatible with the definitions of UGS, mental health and urban biodiversity adopted in this study (See Box 1).

2.2. Data extraction and analytical strategy

A total of 4850 documents were screened through the steps depicted in Fig. 3, resulting in 50 articles included in this review.

Following the PRISMA guidelines (Moher et al., 2009), we conducted and documented the different stages for searching, screening and including records (Fig. 3). The initial search yielded 3744 (after removing duplicates). After screening the title and abstract, 171 full-text studies were assessed for eligibility. During the full-text assessment, articles that met the following criteria were selected:

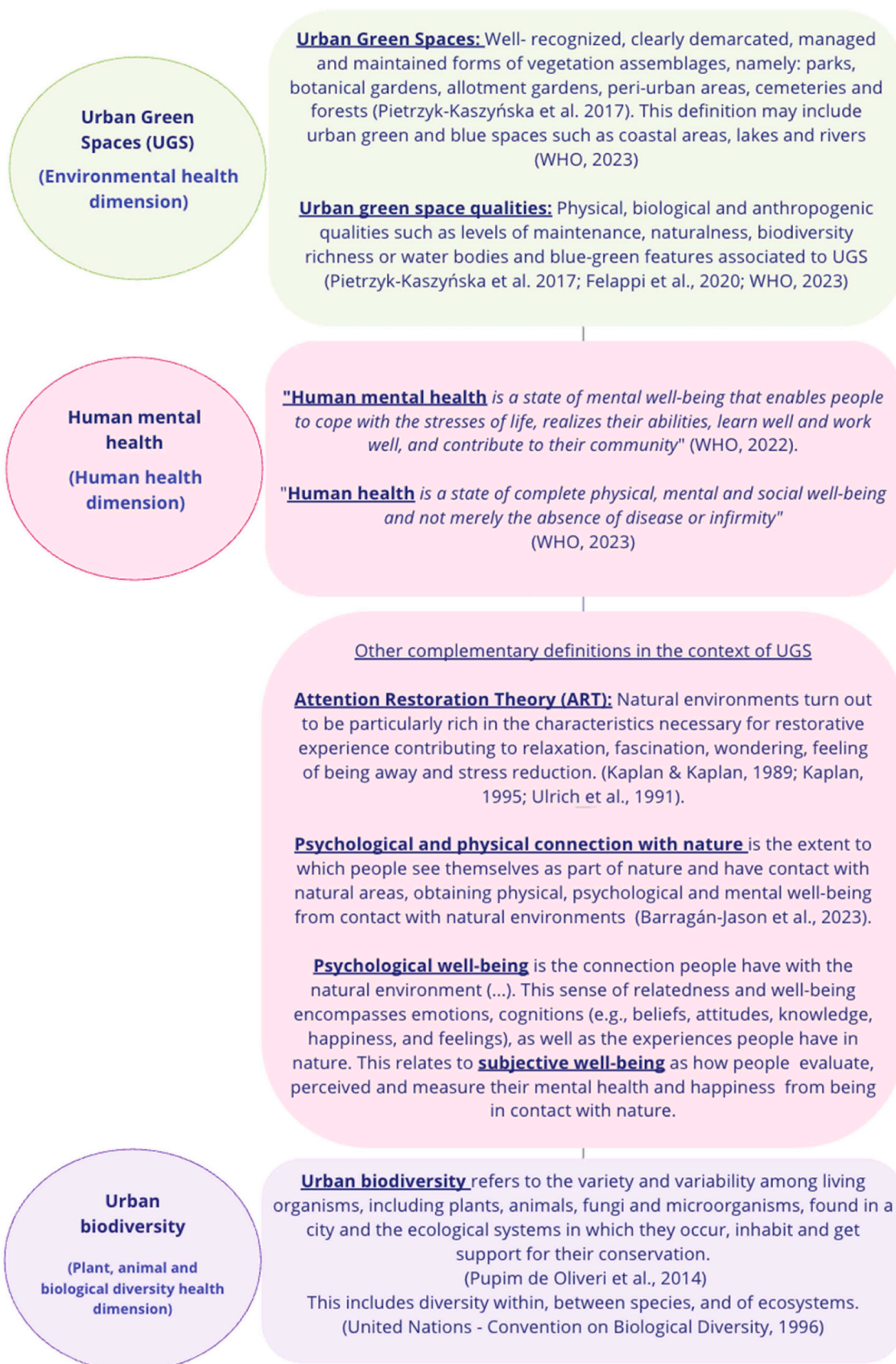


Fig. 3. Box 1. Adapted One Health framework with its three dimensions and associated concepts and definitions.

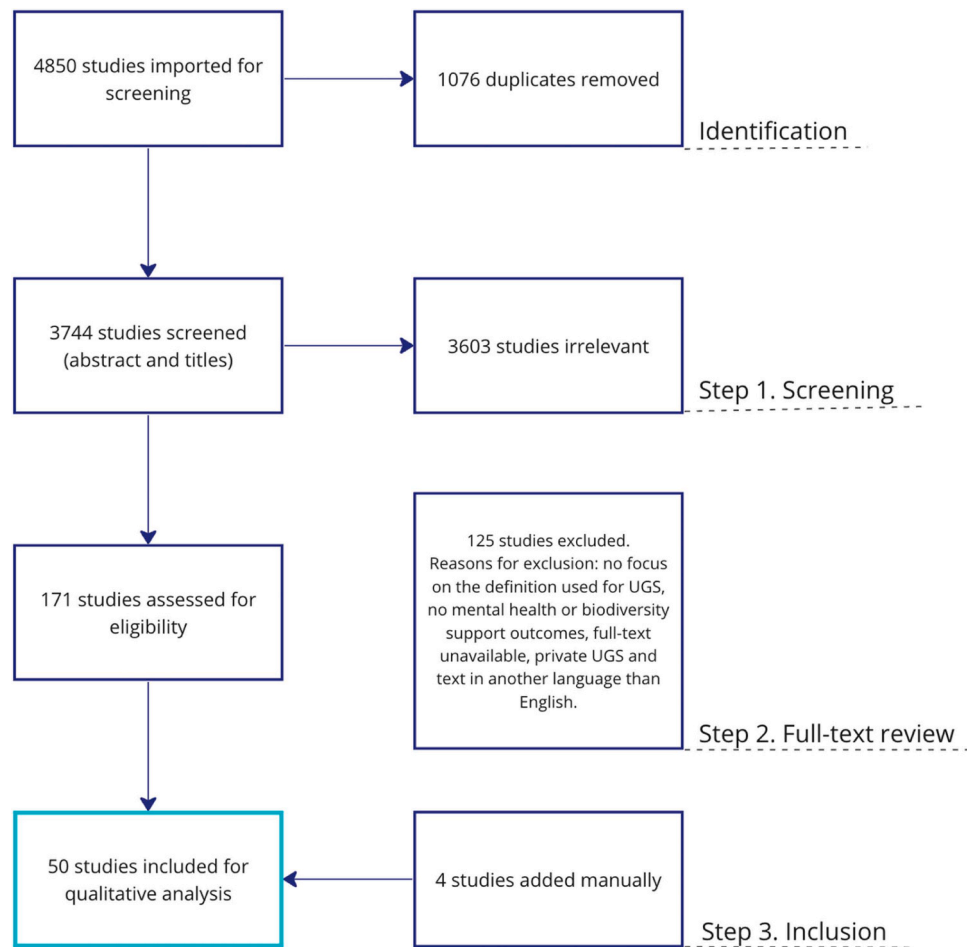


Fig. 4. Selection of publications through the scoping review process.

(a) Studies examined human mental health outcomes in relation to UGS

(b) Studies examined urban biodiversity conservation outcomes in relation to UGS

(c) Studies examined human mental health and urban biodiversity in UGS

(d) Studies compatible with the definitions previously discussed.

This yielded a total of 46 papers included in this review. Additionally, we included four records in the search (Step 3, Fig. 3) by identifying additional and relevant papers highlighted throughout the full-text review and reviewing their reference list. For those records, we used the same search and screening criteria. As a result, 50 studies were finally included and extracted in the qualitative analysis (See Fig. 3 and Table 2). To account for bias in study selection, we used an iterative screening and appraisal approach where at least two co-authors reviewed and discussed each record. The coding and analysis process was carried out in Excel, where we extracted and compiled the main information for each record (See Table 2). We used this information to

identify the main dimensions, interfaces, and emerging themes from each record included in the review. Firstly, we identified the dimensions and interfaces derived from the literature and our adapted One Health approach (See Fig. 2). Secondly, we compiled the main research themes in relation to the dimensions and interfaces previously identified. Finally, we identified and classified each record in one of the three major themes we acknowledged from the literature. These three major themes represent the results of our review. Although this is a qualitative study that included both empirical findings papers and literature reviews, to ensure there was no double-counting, we used an outcome-based strategy. With this strategy, we checked that studies reported in the literature review were not included in the empirical studies, and if they were, we reported only on different outcomes. The extraction template can be viewed in the ESM (please refer to the supplementary material for a full list of papers).

The analysis of the literature was conducted through a qualitative analytical approach that contributed to the identification, classification and analysis of the literature into emerging themes, gaps in knowledge

Table 2

Data extracted from the literature.

Data extracted from the literature
(a) Title, year, author(s), aims, main findings, methodologies and conclusions.
(b) Country, city, and site where research was conducted.
(c) Type of UGS and biophysical characteristics.
(d) Outcomes and methodologies on mental health and/or urban biodiversity.
(e) Methodologies
(f) Socio-economic data (if available)
(g) Insights into the notion of <i>health</i> , including human, biodiversity and environmental health.

and recommendations (Butler et al., 2016). This analysis contributed to identifying the three dimensions that we adapted by the One Health framework. Furthermore, to uncover the different One Health interfaces for our analysis, this assisted in identifying four derived interfaces from the adapted One Health framework (See Fig. 2):

- (1) UGS and urban biodiversity
- (2) UGS and human mental health
- (3) Urban biodiversity and human mental health
- (4) UGS, human mental health and urban biodiversity

These interfaces were used in our analysis, helping us to identify interlinkages and insights to the concept of "health", allowing us to conceive UGS from a One Health approach that links UGS, human mental health and urban biodiversity.

3. Results

The first observation on the resulting papers is that the majority of the literature were empirical findings papers (n=36), and the rest were literature reviews. Cross-sectional studies (n=20) were the most common type of empirical study, followed by comparative studies (n=12) and reviews (n=12). Like the findings from other reviews on UGS (Collins et al., 2020; Felappi et al., 2020), the majority of the literature emanates from studies in cities from the Global North (n=26). There is underrepresentation of literature from Asia (n=9), South and Central America (n=5), Africa (n=1) and Oceania (n=1), which may be because we included only literature in the English language. Most of the papers (n=26) were published during and after the Covid-19 pandemic. Urban parks (n=22) were the most common type of UGS in the reviewed literature, followed by studies that comprised parks and forests (n=9), parks and allotment gardens (n=6), urban forests (n=4), green and blue spaces (n=4), allotment gardens (n=2), parks and botanical gardens (n=2), and cemeteries (n=1).

This review evidenced and highlighted that the One Health framework has been poorly explored in the context of urban green spaces. Only two studies from the review mentioned this framework in relation to urban greening. On the one hand, Felappi et al. (2020) adopt a One Health perspective in a systematic review to identify Urban Green Infrastructure (UGI) qualities that benefit human and animal health. In this review, qualities of UGI such as vegetation coverage, colourful flowers, tree cover and patch areas were evidenced to support human mental health and animal health. On the other hand, Cameron et al. (2020) in a review study that explores how avian biodiversity promotes more positive emotions in citizens, acknowledge the potential of the One Health framework in interfacing human health and biodiversity in urban settings.

Despite the fact that the One Health framework was not represented in most of the reviewed studies, our analysis of the literature through the adapted One Health framework and its derived interfaces (Fig. 2) clearly highlights the linkages between UGS, human mental health and urban biodiversity. When using the adapted framework, three main themes were identified:

- (1) The restorative capacity of UGS
- (2) The restorative capacity of their urban biodiversity, and
- (3) Biodiversity conservation through perceived environmental health, nature connectedness and ecological knowledge in UGS

These themes are interrelated with each other, demonstrating the importance of conceiving the notion of health from a holistic, interdisciplinary, and interlinked approach that integrates people's health, biodiversity, and the urban landscape.

3.1. The Restorative capacity of UGS for human mental health

Much of the literature included in this scoping review provides evidence that green spaces such as urban parks (Palliwoda et al., 2017),

community gardens (Dennis & James, 2016), cemeteries (Nordh et al., 2017), peri-urban areas (Bonilla-Bedoya et al., 2020) and, green and blue spaces (Fisher et al., 2021a,b,c) represent an opportunity for mental health restoration and well-being in cities. Their findings are based on the Attention Restoration Theory, which suggests that spending time in natural environments restores an individual's ability to concentrate and focus attention, acknowledging the capacity of UGS to renew attention, reduce stress and provide feelings of relaxation through a sense of contact with nature (Kaplan and Kaplan, 1989; Ulrich et al., 1991). Moreover, the literature integrates the restorative capacity of these spaces into experiential qualities highlighted in the Attention Restoration Theory, such as effortlessly attracting attention (soft fascination), arrangement of stimuli (coherence), compatibility with the person's needs (compatibility), and the feeling of being away from everyday tasks and activities that demand directed attention (being away) (Kaplan & Kaplan, 1995; 2003) (See Box 1. Human mental health dimension). This topic is therefore explored in the reviewed literature through the bio-physical restorative qualities of UGS, the restorative experience, and an overall understanding of human mental health, comprising human physical health and well-being dimensions.

The literature mostly recognises naturalness as a restorative quality, referring to landscapes with relatively more natural characteristics. Thus, naturalness levels are the degree to which a place is conceived as natural by a continuous gradient between extreme and entirely natural to entirely artificial. For instance, Meyer-GrandBastien et al. (2021) conducted a study in an urban park in Rennes, France, where they identified that different heights of native vegetation and flower strata positively impact mental health restoration and evoke feelings of calm, relaxation and a sense of contact with nature. Likewise, Foo et al. (2016) found that the wildness features of the urban forests in Malaysia were associated with feelings of freedom and calmness while offering the perception of being away of the city. Similarly, in urban parks across the UK, Hoyle et al., (2019) identified that vegetation growing with minimal human intervention and design was more valued for mental health restoration than perceived tidiness and care. These findings evidence that spaces with medium-high-density forests and with a balanced degree of wildness features are considered more contemplative and restorative than areas in UGS completely tended, manicured and managed (Chang et al., 2016; Cameron et al., 2020).

Socio-cultural and individual aspects such as perceptions, preferences, attitudes, nature connectedness and aesthetic values influence the restorative capacity of UGS (Dallimer et al., 2014; Bele & Chakradeo, 2021; Luo et al., 2022). For example, one study in an urban park in Lisbon, Portugal, evidenced that visitors' perceptions, experiences and attached emotions were key to identifying the intangible, emotional, and cognitive bonds that positively influence mental restoration in relation to the biological and physical qualities of the UGS and their biodiversity (Gonçalves et al., 2021). This is aligned with the idea that the restorative capacity of the landscapes also depends on the way people and individuals experience and perceive the space, including aesthetic, visual and acoustic appearance (Nordh et al., 2017). Therefore, qualities such as flowers, waterbodies, bird sounds, landscape heterogeneity, smells, bright colours, the presence of animals, and natural and cultural-related references were found to have stronger restorative effects (Coutts & Hahn., 2015; Ives et al., 2017; Kothencz et al., 2017; Marcheggiani et al., 2019; Wang et al., 2019; Felappi et al., 2020; Deng et al., 2020; Hanson et al., 2021).

The direct exposure to nature, the frequency and the duration of the visit were determinants of the restorative capacity of UGS (Cox et al., 2018; Fisher et al., 2021a; Oh et al., 2021). For instance, visit patterns, perceived naturalness, and visits lasting (>25 minutes) were correlated with improved positive experiential well-being, happiness and perceived restorativeness in green and blue coastal areas in a tropical city (Fisher et al., 2021a). Similarly, perceived biodiversity (Nghiem et al., 2021), nature dose (Cox et al., 2017), and perceived species richness (Methorst et al., 2021) were also identified as key restorative

qualities. External qualities such as accessibility, cleanliness, quietness, lighting, management and feeling safe also impact the restorative capacity and experience of UGS (Cox 2018; Fisher et al., 2021; Nawrath et al., 2022).

Moreover, the literature broadens the meaning of human mental health and integrates physical health and dimensions of well-being. Following this narrative, the literature identifies the benefits of UGS for the hedonic and eudaimonic dimensions of well-being. Hedonic dimensions include qualities for happiness and life satisfaction (Adjei & Agyei, 2015), while the eudaimonic dimension focuses on psychological, therapeutic and restorative functions (Houlden et al., 2017; Ives et al., 2017; Fisher et al., 2021a). Positive impact of these spaces for quality of life (Kothencz et al., 2017), sense of place (Foo, 2016; Hausmann et al., 2016), nature connectedness (Dallimer et al., 2014) and social cohesion (Dennis & James, 2016) were highlighted in the literature as well as the positive link between UGS and physical health through promoting physical activities, recreation and playing (Nath et al., 2018; Nawrath et al., 2022) and by preventing non-communicable diseases and health issues associated to air pollution, climate change and heat waves, recognizing, therefore, that UGS contribute to cope with environmental challenges that may impact human physical and mental health in urban settings (Madureira et al., 2015; Kolokotsa et al., 2020).

Finally, within a specific target population, the reviewed literature illustrates the positive benefits of urban allotment gardens for Alzheimer and Dementia disease among elderly communities (Andreucci et al., 2019) and the importance of managed and unmanaged UGS for the integrative physical and psychological development of children (Vidal & Castro Seixas, 2022). These findings are supported by the general recognition of the potential of UGS as natural and semi-natural settings for health equality through promoting an accessible restorative experience (Cox et al. 2018; Hunter et al., 2019; Bonilla-Bedoya et al., 2020; Marselle et al., 2021). Thus, to guarantee inclusive and accessible UGS, the literature proposes the use of methodologies such as participatory videos or participatory tools such as mobile apps or online platforms designed to collect data and engage residents and other stakeholders in the planning process and decision-making. For instance, Fisher et al. (2021c) in Georgetown, Guyana and Nawrath et al. (2022) in Kathmandu, Nepal, used participatory videos to enhance the multi-sensory experience by identifying characteristics of UGS that benefit the well-being of residents and by improving accessibility, social cohesion and the restorative capacity of UGS. In the case study presented by Fisher et al., (2021c), the videos recorded by citizens along the blue and green coastal areas in Georgetown, Guyana, acted as “vehicles for both participants and decision-makers to engage with the issues surrounding human well-being in urban green and blue spaces” (Fisher et al., 2021c, p. 356), enabling participants to share concerns around the maintenance, accessibility and safety of the coastal areas and concluding that green and blue areas in Guyana contribute to feelings of attention restoration and subjective well-being. Similarly, the use of online and mobile platforms, such as the sentiment analysis tool, a mobile app designed to collect data on benefits for human mental health and quality of life by having contact with botanical features in urban forests, parks, and allotment gardens across cities in Italy, contributed to engaging with citizens to explore in-depth human-plant relationships in UGS. This gave insights into the need to increase vegetation cover for green development and public health in towns and metropolitan areas in Italy (Capotorti et al., 2020). These participatory and innovative methodological approaches are examples of the importance of engaging with citizens and local communities to enhance the restorative capacity of UGS by promoting active participation and discussion around biodiversity-friendly and healthy UGS in urban settings from the global south and the global north.

3.2. The restorative capacity of urban biodiversity

The restorative capacity of UGS is also associated with the interface

between mental health and urban biodiversity. In this interface, the importance of natural landscapes and their associated wildlife in urban areas is explained through evolutionary and social approaches such as the Biophilia Hypothesis that states that human beings evolved in natural environments and developed an innate tendency, fascination and restorative capacity from being in natural spaces and in connection with other ways of life (Carrus et al., 2015; Murgui & Hedblom, 2017; Liordos et al., 2020). Moreover, from a socio-ecological perspective, the literature highlights that perceived plant and animal richness also impact the restorative capacity derived from UGS and its biodiversity (Methorst et al., 2021).

A main emerging theme from the literature reviewed explores the hypothesis proposed by Carrus et al. (2015) of *go greener, feel better* (Carrus et al., 2015, p. 221), which states the correlation between human mental health and perceived biodiversity levels in UGS. For this approach, Carrus et al. (2015) conducted an empirical study in four different types of green areas, varying in the level of biodiversity richness (low vs high) and location (urban vs. peri-urban). The results showed the positive role of biodiversity upon perceived restorativeness, evidencing that peri-urban areas and high biodiversity areas are more likely to exert a restorative effect on their visitors (Carrus et al., 2015). Similarly, Nghiem et al. (2021) found at Windsor Nature Park and Singapore Botanic Gardens that perceived animal diversity and nature exposure is linked to emotional well-being, identifying that perceived bird, butterfly and plant/tree diversity led to greater psychological well-being. In addition, Adjei et al. (2015) and Bele et al. (2021) argue that urban parks and allotment gardens with different levels of vegetation and animal diversity were considered highly restorative spaces in cities, evoking feelings of happiness, social cohesion and promoting biodiversity knowledge. These findings implicitly recognize how the contemplative experience of UGS is interrelated to perceived plant and animal richness while also shaping the narrative that higher biodiverse UGS are healthy environments that support urban biodiversity and citizens' mental health and well-being.

In this sense, the literature reveals that UGS with greater levels of perceived biodiversity promote more positive emotions in humans, resulting in healthy UGS as they support urban biodiversity and human mental health restoration (Cox et al., 2017; Cameron et al., 2020). This link is explored in this body of the literature by researching the benefits of having contact with urban wildlife and recognising that encounters with plant and animal species in UGS are an embodied experience where people interact, perceive, live and connect with nature through its five senses and engage with its fauna and flora through their local and ecological knowledge on urban wildlife (Methorst et al., 2020).

Most of the evidence from the literature focus on how encounters with bird species in UGS promote human health restoration and well-being by attributing to bird species acoustic and visually appealing characteristics, spiritual values, and local knowledge that may have an impact on positive mental health and well-being outcomes (Fisher, et al., 2021a, b; Methorst et al., 2021). Among the benefits of having contact with bird species in UGS, it is highlighted aspects of subjective well-being and sense of place, which are dimensions that embed people's perception and interpretations of the environment, such as identity or symbolic meaning (Hausmann et al., 2016). Moreover, the literature attributes the capacity of bird species to “draw attention/fascination due to colour, movement or song” (Cameron et al., 2020, p. 304), and feelings of happiness associated with listening to bird songs and interacting with bird species in UGS (Adjei & Agyei, 2015; Fisher, et al., 2021a,b).

For example, one study conducted in coastal and green areas in Georgetown, Guyana, concluded that people's well-being experience could relate to bird sounds and particular species combinations of birds that promote fascination and positive conservation attitudes toward wildlife in UGS (Fisher et al., 2021a). Likewise, Cox et al. (2017) revealed in an empirical paper that vegetation cover and afternoon bird abundance were associated with a lower prevalence of depression, anxiety and stress. Similarly, one study (Marselle et al., 2021) identified

that greater bird richness was related to greater levels of life satisfaction, positive affect, psychological well-being and buffer noise pollution for the traffic. No evidence of the impact of birds on physical health was mentioned in the reviewed literature (Chang et al., 2016; Methorst et al., 2021).

Even though most of the literature identifies a positive correlation between urban biodiversity, mainly bird species, and mental health, it is necessary to extend the research to other species and contemplate also their negative health outcomes. As Liordos et al. (2020) state, cognitive variables such as social norms, attitudes and learned behaviors can explain relationships and interactions towards the natural world, in which likeability, desirability and positive and negative emotions enhance the understanding of human-wildlife interactions. This shows that some animal and plant species might be more socially and ecologically valued than others, impacting their potential for human health and maybe underestimating their importance for ecosystem functionality and their significance for biodiversity conservation efforts in UGS (Methorst et al., 2020).

Finally, aligned to the original purpose of One Health, only two studies (Felappi et al., 2020; Marselle et al., 2021) included a brief discussion on conflicts from having contact with urban biodiversity in relation to the spread of zoonotic diseases and their potential negative effects on human mental health and well-being. These suggest that enhancing biodiversity richness may increase the risk of vector-borne diseases, declining, therefore, human physical and psychological well-being and adversely affecting the positive effects of health restoration resulted from having contact with nature in UGS.

3.3. Biodiversity conservation through perceived environmental health, nature connectedness and ecological knowledge in UGS

Following the link between UGS and urban biodiversity, there was a small body of literature that discussed in-depth how UGS contribute to supporting existent biodiversity and promoting its conservation in cities. What literature exists mainly explores their contribution through two main approaches: 1) perceived environmental health and 2) ecological knowledge. Both narratives expose how human-animal-plant interactions, local knowledge exchange, socialisations, and contact with nature and biodiversity are key components for promoting biodiversity conservation in UGS.

The first narrative is implicitly associated with the idea of *go greener, feel better*, discussed previously in relation to urban biodiversity and mental health. In this case, the literature recognizes that UGS with higher diversity of plant richness and vegetation structures help to support existing biodiversity and, therefore, to be a reservoir for biological diversity in cities (Ofori et al., 2018), while also increase ecosystem functionality (Madureira et al., 2015; Barrico & Castro, 2016; Chang et al., 2016; Gunnarsson et al., 2017).

For example, Ofori et al., (2018) surveyed small mammals in the University of Ghana botanical garden, a setting with high levels of native vegetation and an adjoining built-up environment. The results showed that this UGS supports the habitat of small mammals and other animal species, representing a space for ecological connectivity and providing habitat support in a sprawling city. In addition, the authors recognise co-benefits derived from human-animal-plant interactions such as outdoor recreation, contact with nature and enhance awareness on plant and animal conservation. Similar derived co-benefits were identified by Palliwoda et al. (2017) through systematic interviews across urban parks in Berlin, where they identified that activities such as urban foraging support human-plant interactions that stimulate social cohesion and exchange knowledge on native plant species.

Along the same line, Muraret et al., (2015), Barrico & Castro (2016), and Bele et al. (2021) recognize that community knowledge, local perceptions and nature connectedness in UGS may be a starting point to involve citizens and local communities in biodiversity conservation agendas. Muraret et al. (2015) and Bele & Chakradeo., (2021) draw on

the idea that how people perceive, value and interact with urban nature may contribute to addressing ecological issues by raising awareness of biodiversity conservation and ecosystem services provided by UGS and their biological and environmental diversity. Similarly, Barrico & Castro (2016) argue for the need to exchange local ecological knowledge by engaging with local communities and citizens through reinforcing public participation, communication, and education programs. This is in order to achieve sustainable urban public policies that enhance biodiversity conservation efforts and enhance nature connectedness and social cohesion in UGS.

This body of literature gives insights into the interface between UGS and urban biodiversity, opening future discussions on how public engagement and exchange of local knowledge should be integrated into biodiversity conservation efforts. They also highlight the recognition of UGS as potential habitats that contribute to supporting biological diversity by increasing ecological knowledge, contact with urban nature and expanding on conceptions of healthy UGS that integrate human health, biodiversity health and environmental health.

4. Discussion

Through our adapted One Health framework, we analyzed scientific literature on UGS to explore, from an interrelated and interdisciplinary perspective, the impact of UGS on human mental health and urban biodiversity. The analysis of the literature yielded three main results, highlighting the positive restorative capacity of UGS, their biodiversity, and the importance of ecological knowledge to create awareness of urban biodiversity conservation in UGS. By reflecting on the findings of this review, in the following section, we will discuss qualities of urban green spaces in relation to health restoration, the role of urban biodiversity for human mental health, and insights form the literature on the idea of healthy UGS. Along the discussion, we will highlight gaps, future perspectives, and limitations and point towards ways to enhance the One Health framework for future studies and for its application in the design and urban planning of healthy UGS.

4.1. Restorative qualities and opportunities to enhance healthy and inclusive UGS

Though UGS can be used to describe a great many different spaces and different urban contexts, this review presents evidence on how UGS in general may have biological and physical features that contribute to experiencing them from a restorative perspective. It highlights that UGS, such as parks, forests, allotment gardens, cemeteries, and green and blue spaces, are settings that promote mental health restoration and overall well-being. Moreover, it shows evidence of the importance of aesthetic qualities such as naturalness levels, types of vegetation, wildness features, waterbodies, bright colours, smells, and the presence of flowers and animals. These characteristics have been broadly attributed in the scientific literature as restorative qualities to be integrated in the management, planning and design of healthy green spaces in cities (Berto et al., 2018; Felappi et al., 2020; Olszewska-Guizzo et al., 2022).

Associated with the restorative capacity of UGS, this review also identified that these spaces offer an embodied and multi-sensory restorative experience in which the biophysical features and the connection with nature and urban biodiversity contribute to the restorative capacity of UGS. However, to enhance the capacity of these spaces, it is important to include a further discussion around issues of accessibility, inclusion and feeling safe in order to promote and contemplate UGS as natural and semi-natural areas that contribute to health equity in cities. This discussion is relevant in urban settings, where access to natural environments may affect disproportionately socially and economically deprived communities (Bonilla-Bedoya et al., 2020; Marselle et al., 2021) or impact vulnerable populations such as elderly residents (Andreucci et al., 2019; Grey et al., 2023), children (Vidal & Castro Seixas, 2022) or women (Mayen Huerta & Utomo, 2022)

populations that, as our results showed, are underrepresented in the scientific literature on UGS. This was evident in our review, where only two papers focused on children and elderly communities as target populations. This evidences the need to continue working for a One Health approach that encourages more inclusive and collaborative research, engaging with local communities, minorities and vulnerable populations, creating dialogues and collaborations between citizens, stakeholders and decision-makers for the promotion, design and planning of healthy and inclusive UGS.

As an opportunity to engage with citizens, the literature proposes the use of participatory methodologies such as videos (Fisher et al., 2021; Nawrath et al., 2022) and participatory online tools, platforms and mobile apps to measure socio-ecological and health values towards UGS and its biodiversity (Capotorti et al., 2019). Likewise, there is positive evidence for using citizen or community science to improve physical and mental health in cities (Higuera-Mendieta et al., 2023; leBrasseur, 2023), for assessing the potential of UGS for biodiversity and ecosystems and cultural services (Dampney et al., 2022) and to identify uses and human connection to nature in UGS (Cambria et al., 2021). This type of research approach and methodologies that integrate multiple viewpoints while capturing the complexities of the real world may be a vehicle for both participants and decision-makers to engage with the issues and solutions surrounding human mental health and well-being while enhancing citizens' health rights through accessible, inclusive and safe UGS (Bonilla-Bedoya et al., 2020; Fisher et al., 2021c).

4.2. The role of urban biodiversity for human mental health in UGS

This review also revealed that UGS are potential settings in cities designed and managed for mental health restoration and recreation, underlining that contact with urban biodiversity impacts citizens' mental health and overall well-being. Most of the literature recognizes the positive outcomes derived mainly from having contact with bird species in UGS, highlighting their restorative qualities associated with aesthetics, ecological knowledge, and acoustic and visual appearance, exhibiting different colours, forms, plumage, bird songs and captivating behaviours (Cox & Gaston, 2016; Hoyle et al., 2017; Marselle et al., 2021; Methorst et al., 2021). In relation to this finding, there is evidence that activities such as bird-watching improve psychological restoration and social well-being while increasing bird and environmental conservation awareness and promoting the exchange of ecological knowledge (Cox et al., 2017; Randler et al., 2022; Zieris et al., 2023). For example, Zieris et al. (2023) examined the effects of wild bird observation on the health and well-being of nursing homes and their residents, evidencing that bird watching is an effective and inexpensive intervention that increases cognitive resources, mobility and social well-being among elderly residents. Moreover, as Shrode (2012) and Jepson & Ladle (2015) state, the popularity of bird-watching is reflected by an abundance of bird identification programs, mobile apps and online guides that enhance the experience of bird-watching and bird identification while stimulating park visits, recreation activities and enhancing didactic and educational programs in UGS.

The review showed most studies relied on certain taxonomic groups, mainly studies focusing on birds, while other taxonomic groups, such as mammals, insects, amphibians or reptiles, were less studied and mentioned in the literature. This highlights a gap in the scientific literature and the need to include other species and groups of wildlife in consideration. Including it in future research can improve our understanding in regards to their contribution not only to human health, but also, their significance to biodiversity conservation and ecosystem functionality. Furthermore, a better understanding of social norms, likeability, desirability, and positive and negative emotions towards urban wildlife may enhance our understanding of human-nature relationships in UGS (Liordos et al., 2020; Methorst et al., 2020). This may contribute in the promotion of multispecies or more-than-human cities by expanding our idea of how citizens relate to urban biodiversity and

opening opportunities to design and plan cities that stimulate coexistence experiences between human and non-human residents (i.e. animals, plants and other living beings that inhabit and interact in urban ecosystems) (Houston et al., 2018; Van Patter, 2023).

On the other hand, the study of the interface between human mental health and urban biodiversity opens the opportunity to research in-depth the adverse effects of having contact with wildlife on human mental health, including perceived ecosystem services such as negative feelings (i.e. feelings of fear, stress, anxiety, insecurity, or even physical injuries) (Liordos et al., 2020; Methorst et al., 2020; Rodgman et al., 2024), the risk of zoonotic diseases (Aerts et al., 2018; Marselle et al., 2021), pests (Blasdel et al., 2022) and emerging diseases resulted from human-animal contact (Gandy, 2022). This potential field of study, which aligns with the original purpose of One Health, may be relevant for the management, planning and adaptation of UGS in settings that are vulnerable to the spread of vector-borne diseases (Bardosh et al., 2017; de Leeuw, 2021) and for the assessment, prevention and design of UGS in cities in risk of spread of emerging diseases due to warmer temperatures and rapid environmental changes associated to climate change and urbanization (Egid et al., 2023; Marselle et al., 2019). Other disservices, such as decreased aesthetic value, perceived harms, nuisances, and safety concerns, can negatively impact overall health and influence how UGS are experienced, used, valued, and managed (von Döhren and Haase, 2015; Lyytimäki, 2015). A One Health approach can inform collaborative and multifaceted strategies to address these challenges within urban planning and management, ultimately contributing to mitigate risks and maximise the benefits of UGS.

When considering the biophysical and botanical qualities of UGS in the light of the interface of UGS, urban biodiversity and human mental health, this review got insights into restorative qualities from perceived plant richness and abundance, showing evidence that UGS with different densities of vegetation, naturalness levels, wildness features and different types of native vegetation is associated with feelings of relaxation, well-being and mental health restoration. This evidence aligns with scientific literature that demonstrates that there is a preference for UGS with higher naturalness levels and biodiversity conditions over medium or low biodiversity settings (Aram et al., 2022). This contributes to shifting the conception of UGS as environments highly intervened, manicured and managed towards urban ecosystems with low-medium human intervention instead (Chang et al., 2016). Likewise, the reviewed literature reveals that UGS with higher perceived levels of biodiversity may be socially and ecologically valued as "healthier" ecosystems associated with microhabitats that contribute in the support of large diversity of fauna and flora and in turn to human mental health restoration and well-being.

4.3. Healthy UGS from an adapted One Health perspective

Through the analysis of the literature using our adapted One Health framework, we got insights into the notion of what a "healthy UGS" mean at the interface of human mental health, urban biodiversity and environmental health. The analysed studies attributed a positive co-relationship between plant richness and bird richness and their contribution to human mental health. UGS with higher perceived plant richness, such as natural and semi-natural spaces with spots containing higher vegetation structures and plant diversity, were indirectly conceived as "healthier" ecosystems as they are believed to host most of the birds' species, richness and abundance in urban settings, having, in turn, positive benefits to human health and improving contact with nature in cities.

This finding relates with what Cameron et al. (2013) state that landscapes with high bird richness, for example, might be an indicator of other nutritional resources in terms of fruit, seeds, and invertebrate food, as well as suggesting the presence of water and other living beings interacting within the environment, and the provision of ecosystem services related to climate regulation, air quality and enhancement of

ecological functionality (Lan et al., 2022; Paudel & States, 2023).

Likewise, biodiverse habitats may promote a stronger immune response due to greater exposure to a wide range of microbial organisms (Cameron et al., 2020; Marselle et al., 2021; Robinson et al., 2024) and improve mental health restoration (Meyer-GrandBastien et al., 2021) and psychological well-being (Mavoa et al., 2019) by providing spaces for people to embody restorative and sensory experiences; in physical and psychological connection with urban nature and wildlife in cities.

This also illustrates that biodiversity is a key indicator of human and environmental health (Marselle et al., 2019, 2021) and an important aspect of urban sustainability (Beute et al., 2020), recognising that humans are an integral part of the ecosystem and that, accordingly, a properly managed environment must be ecologically and socially sustainable (Chang et al., 2016). Likewise, these approaches give insights into how the notion of “health” is conceived in light of the interface between environment, people’s health and biological diversity in urban settings and from a One Health perspective.

This idea of “healthier UGS” for people, biodiversity and the environment may be aligned with international agendas that aim to make cities more sustainable and resilient towards future environmental and health challenges associated with climate change, biodiversity loss and rapid urban sprawl (e.g. UNDP, Sustainable Development Goals. Goal 11, (UNDP, 2023)). In this sense, the use of the adapted One Health framework in urban planning may represent an opportunity to conceive UGS as a socio-ecological-health complex system which is constantly changing and adapting to external situations and that needs interdisciplinary and cross-sectoral collaborations. This requires efforts that engage with citizens, local communities, and multiple stakeholders to uncover together the idea of a “healthy UGS”. Moreover, it contributes to conceiving UGS as a multifunctional solution to cope with social, environmental and health challenges locally and globally.

Finally, in times of poly-crisis – from the climate crisis to the biodiversity crisis to increasing socio-economic marginalisation, to a public health crisis, to a crisis of governance. And at this time of unprecedented uncertainty, there is the need to think novelly across systems and disciplines and to generate new connections for policy application. The One Health framework speaks to transformative governance (participatory and integrative approaches) and yet also speaks to the integration and broadening of our notion of health towards an interrelated concept that involves humans in relation to biodiversity and the urban environment. This is positive in a framework that could have a broad appeal and thereby have an important role in defining discourses and indicators for policy implementation and empowerment of communities, moving towards the design and planning of inclusive, healthy and restorative green spaces in cities.

4.4. Opportunities to expand One Health for UGS

We recognize that One Health is an interdisciplinary and multidisciplinary theoretical framework that was initially conceived to create a dialogue between veterinary and medical sciences for the assessment and prevention of zoonotic diseases (WHO, 2020). However, when exploring the scientific literature on UGS from an adapted One Health approach, it is evident that the interdisciplinary dialogue needs to be extended to include experts on urban ecology, urban planning, public and global health, and social sciences. The inclusion of theoretical perspectives and methodologies from different disciplines may contribute to enriching this framework and adapting its applicability in different social, health, and environmental contexts in cities of the Global North and the Global South. This will also contribute to engaging with current debates around One Health that may enhance the study of UGS from a comprehensive perspective.

In this sense, and despite the limited engagement of One Health with social sciences (Van Patter et al., 2023), this review included literature that reported socio-cultural and qualitative perspectives towards UGS and their biodiversity, evidencing the potential of One Health to engage

with social sciences and their participatory and qualitative methodologies to uncover citizens’ perceptions, local knowledge, preferences and restorative qualities of UGS. However, we believe that further collaborations with relevant theoretical debates from the social sciences and environmental humanities, such as more-than-human conceptualizations, may contribute to the One Health framework by recognising that, as Lainé & Morand (2020) highlight, humans are an “integrated part of most ecosystems, not only influencing but being influenced, and that their physical and mental health, now and in the future, are intrinsically linked with the environment and the biodiversity” (Lainé and Morand, 2020, p. 3). This theoretical approach offers an opportunity to move One Health from its anthropocentric roots (Lainé and Morand, 2020) towards a framework that encourages to study the notion of *health* by uncovering human-nature relationships in the era of the Anthropocene (Kirksey & Helmreich, 2010), recognising that human and non-human agencies shape the environment and influence the health of people and the broader ecosystem.

The more-than-human links to all categories and provides another way of thinking through the model that is now being taken up by scholars (Hinchliffe, 2015; Lainé and Morand, 2020; Maller, 2020). This provides an opening for others to play with the model acknowledging the importance of thinking systemically and across fields as well as looking for opportunities to further support urban greening and urban biodiversity in urban landscapes that are increasingly becoming more dense.

Future studies on One Health may benefit from integrating a more-than-human approach, as it may contribute to integrating local knowledge in public health and environmental discussions (Quinlan & Quinlan, 2016), increasing collaborations and public and institutional engagement in scientific research and policy-making. Furthermore, this approach may encourage investigating how human-animal-plant-environment interactions and relationalities impact human and non-human health in urban settings. This opens the opportunity to explore the notion and definition of health in a One Health context, comprising the interface between people, biodiversity and the environment and by including socio-ecological and health approaches that help shed light on what *health* and *healthy UGS* mean in different urban contexts.

4.5. Limitations

This review included literature on urban green spaces, such as urban parks, allotment gardens, botanical gardens, urban forests, blue and green spaces and cemeteries from a One Health perspective that comprises three adapted dimensions, namely human mental health, urban biodiversity and environmental health in the UGS context. However, one of the limitations we encountered when conceptualizing the adapted One Health was the lack of definitions towards notions of urban biodiversity health and environmental health. We used and explored the literature, drawing upon a broader definition of urban biodiversity (Puppim de Oliveira et al., 2014; United Nations (UN), 1996), and extended the notion of environmental health towards the definition of UGS and biophysical qualities of UGS (Pietrzyk-Kaszyńska et al., 2017; WHO, 2023). After reviewing the literature, we identified proxies such as perceived biodiversity (Marselle et al., 2021; Meyer-GrandBastien et al., 2021; Muratet et al., 2015), biodiversity richness (Adjei & Agyei, 2015), naturalness levels (Carrus et al., 2015) or bioindicators (Chang et al., 2016) to account for biological and environmental health. These “proxies” may be applied to future research exploring the linkages between UGS, urban biodiversity and human mental health from a comprehensive perspective. Similarly, we recognise that we focus only on the dimension of human mental health, but this framework may be adapted and applied to uncover other dimensions of human health, for example, analysing the contribution of UGS to preventing communicable (Adhikari et al., 2019; Liu et al., 2019) and non-communicable diseases (Asri et al., 2022; Labib et al., 2020; Wang & Tassinary,

2024), or promoting physical activity (Juul & Nordbø, 2023; Wang et al., 2021). Likewise, the adapted One Health framework opens the opportunity to continue exploring the benefits of other types of greenery in cities such as street trees (Marselle et al., 2020), green walls and rooftops (Cardinali et al., 2023) or even, green spaces with low human management and intervention (i.e. brownfields, post-industrial sites or wastelands) (Rupprecht et al., 2015). This can, therefore, extend our understanding of how the quality of urban nature and urban greening impacts human health and biodiversity conservation. Finally, and despite the fact that we included in our extraction template information related to socio-economic data, there was poor discussion in the reviewed literature on how the implementation of UGS may impact socio-economic dynamics, such as their impact on social inequality (Csomós et al., 2021; Nasri Roodsari & Hoseini, 2022) or green gentrification (Anguelovski et al., 2022) dynamics that affect the urban landscape and the spatial organisation of cities and that should be considered when thinking on the creation of urban policies and planning to implement inclusive, healthy and sustainable UGS for everyone and from a One Health perspective.

5. Conclusions

Using an adapted One Health approach that explores linkages between human mental health and urban biodiversity in the context of UGS, such as parks, allotment and botanical gardens, forests and cemeteries, this literature review recognised that UGS contribute to human mental health and urban biodiversity conservation in cities by encouraging physical and psychological connection with urban nature and promoting exchange of ecological knowledge on urban wildlife. The conceptualization of One Health we proposed for the analysis of the literature drew upon the recognition that UGS are complex socio-ecological and health systems that require a comprehensive and interdisciplinary analysis, including insights on human health, biodiversity health and environmental health in the UGS context. Through our One Health analysis, we identified different interlinkages that gave us insights into how human mental health is interrelated to urban biodiversity. This helped us to uncover the notion of "healthy UGS" as green areas with greater biodiversity that help to enhance ecological functionality and promote human mental health restoration and mental well-being. We conclude that One Health is a framework to continue extending our knowledge on the notions of *health* and *healthy UGS*, including opportunities for interdisciplinary and cross-sectoral collaborations that help to investigate UGS as more-than-human worlds, comprising people, biodiversity and urban ecosystems. Likewise, it is an opportunity to continue uncovering notions and ideas of health to design, plan and create policies that respond to global and local social, ecological and health challenges, and in contexts where UGS may represent a multifold solution towards making cities more resilient, healthy and sustainable for everyone.

CRedit authorship contribution statement

Natalia Rodriguez Castañeda: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Visualization, Validation, Writing – original draft, Writing – review & editing. **Melissa Pineda-Pinto:** Formal analysis, Data curation, Validation, Writing –review & editing. **Natalie M. Gulsrud:** Data curation, Validation, Writing – review & editing. **Clair Cooper:** Data curation, Writing – review & editing. **Mairéad O'Donnell:** Data curation, Writing – review & editing. **Marcus Collier:** Formal analysis, Validation, Writing – original draft, Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare no conflict of interest.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ufug.2024.128489.

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