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FOCUS ARTICLE

Urban freshwaters, biodiversity, and human health and well-being: Setting an interdisciplinary research agenda

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The findings of a national workshop that explored the social and environmental impacts, challenges, and research opportunities associated with the role of urban freshwaters for improved public health are discussed. Bringing together the collective expertise of academics, practitioners, policy, and user-groups from urban aquatic ecology and human health backgrounds, this commentary develops a progressive agenda for future research by synthesizing current understandings and knowledge of urban aquatic biodiversity relative to health-related ecosystem service outcomes, from a cross-sectoral and cross-disciplinary perspective. Key areas include (a) a need for greater interaction between sectors to maximize opportunities for collaboration and to promote the cobenefits (both environmental and health) associated with urban freshwater ecosystems; and (b) the need for a unified understanding and operationalization of the definition of aquatic biodiversity across sectors and disciplines, to improve our understanding of whether actual freshwater biodiversity or the perception of biodiversity is important for maximizing gains in health. Methods of valuation relating to ecosystem services and resource allocation and investment in urban freshwaters are critical in ensuring that research addresses the pathways and contexts within which health and environmental benefits from blue space can be maximized.

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KEYWORDS
freshwater, urban, biodiversity, health, blue space

1 | INTRODUCTION

Over half of the world's population now live in urban areas (United Nations, 2014). It is generally accepted that urbanization can radically alter biodiversity (Aronson et al., 2014; Dearborn & Kark, 2010; Faeth, Bang, & Saari, 2011; McKinney, 2008) and that alterations in ecosystem structure and function through changes in species composition, abundance, richness, and evenness may have important repercussions for human health and well-being (Dallimer et al., 2012). Yet, while research has found that urban aquatic environments ("blue spaces") can bring positive health benefits (Völker & Kistemann, 2011), the specific environmental qualities that offer the greatest benefits to health-related ecosystem services remain poorly understood (Dallimer et al., 2012; Wheeler et al., 2015).

Current predictions suggest that the global population is increasing, with 66% of individuals expected to reside in towns and cities by 2050 (United Nations, 2014). As a result, urban water bodies may be subject to multiple stressors, despite knowledge that their maintenance and functioning is vital for the provision of many important urban ecosystem services. The "natural capital" (the stocks of natural assets from which ecosystem services derive) contained within these urban blue spaces is, in many cases, distinct from that of other urban natural features. For example, the specific heat capacity of water results in services that regulate the urban climate, the water itself represents a commodity that can be used as drinking or irrigation water, and the morphology of the water bodies retains water to regulate hydrological flows through the landscape. However, the conversion of capital to service is hindered through human modifications to those water bodies. Significant of these are alterations to the hydrological characteristics and point and nonpoint source pollution (Mancini et al., 2005). However, while such stressors can impact upon biodiversity and ecosystem function, there has been little work done to demonstrate the link between modifications to the physical or natural habitat and the flow of ecosystem services derived from that habitat. Further research needs to consider the quantitative evidence for the link between anthropogenic disturbance and ecosystem service provision. The UK Department for the Environment, Food and Rural Affairs' (Defra) 25 year plan to improve the environment (Defra, 2018) notes that there have been significant losses to species across terrestrial and freshwater habitats in the last 50 years, largely due to pollution and land use change. Such pressures are seen across the world, in both developed (Eigenbrod et al., 2011) and developing nations (Mundoli, Manjunath, & Nagendra, 2015). This situation presents both challenges and opportunities for aquatic biodiversity and for the human health benefits associated with urban aquatic environments.

The literature is increasingly supportive of the health and well-being benefits obtained from exposure to the natural environment (Frumkin et al., 2017; van den Bosch & Sang, 2017). The salutogenic effects (an approach that focuses on the factors that cause health and well-being rather than the factors that cause disease, Antonovsky, 1996) include reductions in anxiety and stress (Roe et al., 2013), improved self-reported health (Wheeler et al., 2015), improvements in physical health (e.g., obesity (Lachowycz & Jones, 2011), morbidity (Maas et al., 2009), and increased social contact (Pretty et al., 2011). Similarly, blue space provides some health and well-being benefits. While the evidence overall reports positive associations between green space and health (van den Bosch & Sang, 2017), further scrutiny of the evidence linking biodiversity of green spaces as a mechanism for improved health outcomes has proved inconclusive (Lee & Maheswaran, 2011; Lovell, Wheeler, Higgins, Irvine, & Depledge, 2014; Markevych et al., 2017). This is especially true for aquatic environments (Völker & Kistemann, 2011) where health links with biodiversity are lacking. Therefore, furthering understanding in this area may have important cobenefits for improving human health (van den Bosch & Sang, 2017), improving biodiversity and ecosystem services, and possibly catalyzing people to be more supportive of biodiversity conservation and management strategies.

Drawing on the collective expertise of academics, practitioners, policy, and user-groups from urban aquatic ecology and human health backgrounds, this commentary reports on key issues identified during a two-day interdisciplinary workshop held at University College London in April 2015. There were 20 participants (including the authors) representing the following disciplines and sectors: Natural History Museum, Environment Agency, Defra, Natural England, Canals and Rivers Trust, Lambeth Borough Parks, The Rivers Trusts, in addition to academics from a range of disciplines and subdisciplines including freshwater ecology, ecosystem services, environment and health, health geography, environmental economics, health inequalities, and "bluehealth" specialists.

The aim was to develop a progressive agenda for future research by synthesizing current understandings and knowledge of urban aquatic biodiversity relative to health-related ecosystem service outcomes, from a cross-sectoral and cross-disciplinary perspective. The workshop was structured around a set of themes to guide discussions that addressed: establishing the current knowledge state on urban aquatic biodiversity; the relationship between urban fresh waters or "blue space" (all visible surface waters in urban areas') (Völker, Baumeister, Claßen, Hornberg, & Kistemann, 2013), and human health and well-being; social and cultural valuations of blue space; and the methodologies that underpin the various academic and practitioner fields. This article discusses the outcomes in an agenda-setting framework supported by expert consultation and evidenced by current literature, and provides an outline for future research that seeks to maximize the potential for both urban freshwater biodiversity and health-related ecosystem service outcomes.

First, we introduce biodiversity, then present an overview of current knowledge on the positive associations between biodiversity and human health and well-being. Based on a framework of discussion topics addressed during the course of the workshop, we then identify some of the challenges involved in promoting freshwater biodiversity in urban environments as a necessary or desired component for improved human health and well-being. In so doing, particular focus is placed on understanding the contested nature of whether biological diversity results in greater health gains; factors influencing public perceptions of biodiversity and use/nonuse of urban blue space; and the potential for different forms of appraisal to influence the valuation of blue space. In the final section of this paper, we discuss the relative (dis)benefits of uncoupling research and practice on green and blue space, emphasize the value of mixed methodologies and report on possible approaches that have the potential to develop further understanding of the links between urban aquatic biodiversity and human health and well-being. Figure 1 provides a framework summarizing key outcomes and suggestions for future directions.

2 | WHAT IS BIOLOGICAL (BIO)DIVERSITY

Biological (bio)diversity is defined by the Convention on Biodiversity (CBD) as "the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (Convention on Biological Diversity, n.d.). Biodiversity is a key element that underpins the ecosystem functions and process that provide humans with vital goods and services (Schwarz et al., 2017). These "services" have historically been separated into four broad categories: regulating (e.g., climate and disease regulation; pollination), supporting (e.g., primary production), provisioning (e.g., food and freshwater), and cultural (e.g., recreation, health, and well-being) (Millennium Ecosystem Assessment, 2005; Sukhdev et al., 2010). However, supporting services are now not generally used and rather recognized as being part of the underlying structures and processes that characterize ecosystems (Haines-Young & Potschin, 2018). In this ecosystem services context, we consider aquatic biodiversity as providing a number of services that have both direct and indirect effects on human health and well-being (NEA, 2011).

One key finding relates to the interpretation of biodiversity, in that despite the CBDs recognized definition of biological diversity, it is likely to mean different things to different people (Fischer & Young, 2007). It was argued that what constitutes biodiversity has different meanings to individuals within different academic disciplines and sectors, so that outside of the ecological disciplines, aquatic biodiversity is often used interchangeably with "blue space" and quite often the presence of charismatic species or a large number of single species would constitute "biodiversity" (Figure 1). Priority outcomes are also discipline and sector specific across ecological backgrounds and those from health and well-being backgrounds. For the former group, biodiversity tends to equate most closely with the Convention on Biodiversity definition, with not only species

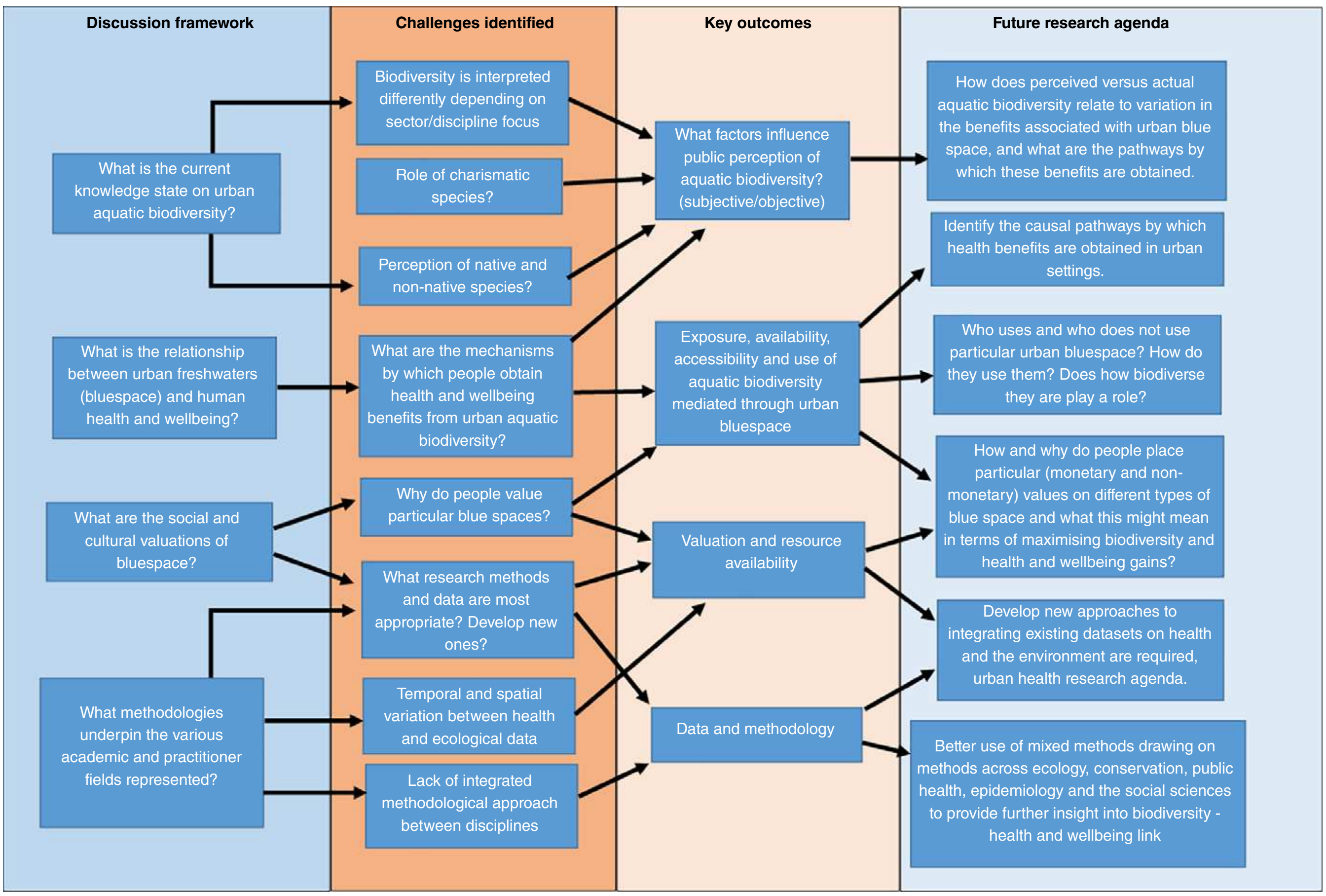

FIGURE 1 Summary of the discussions and outcomes of the urban aquatic biodiversity and human health workshop within a conceptual framework showing the key challenges, outcomes, and future directions relating to an interdisciplinary cross sector working agenda to understand the role of biodiversity for health and well-being-related ecosystem services

richness, but also species appropriateness, considered vital for robust ecosystem functioning. For the latter group, biodiversity was equated primarily with their social and cultural value or even simply the presence, or indeed absence, of particular charismatic species, and seen as one possible avenue through which human well-being could be enhanced. Participants discussed that taking in to consideration and then operationalizing the different interpretations of biodiversity is therefore, likely to constitute a key challenge to successful intersectoral and interdisciplinary working in promoting urban biodiversity for health. This is particularly true when aspirations to improve biodiversity in urban settings for the inherent value of doing so, may be at odds with practical considerations of budget allocations for maintaining and improving existing sites, when perhaps the perception of a biodiverse environment may have similar health effects (Dallimer et al., 2012). Given this potentially critical barrier, one potential solution that was discussed was to invoke a working usage of the CBDs definition of biodiversity within a blue space framework. This may help to address these differences in understanding from the outset. Defining terms that are understood and agreed by all involved is vital if interdisciplinary working is to result in effective outputs, particularly when the outcomes prioritized across different fields may seem, at least on the surface, to be at odds.

To date, there has been little critical analysis of what different disciplines and sectors might consider to be effective outcomes of maintaining, improving or indeed loss of biodiversity. This is surprising given that the language of biodiversity now permeates the literature on ecosystem services and has a strong presence in UK policy documents (Defra, 2018; Lawton et al., 2010; NEA, 2011). While recognizing the inherent value of robust ecosystem functioning, the ecological definition of biodiversity does not necessarily cohere with positive outcomes for human health and well-being. While there is some evidence that suggests positive health effects of indirect (Wall, Nielsen, & Six, 2015) and direct exposure to species rich environments, for example (Fuller, Irvine, Devine-Wright, Warren, & Gaston, 2007) the pathways are difficult to elucidate, particularly given that species poor, urban blue space for example, might hold an important health function if it is a place in which regular physical activity is undertaken, or where therapeutic well-being is experienced based on aesthetic enjoyment. For example, in a semiquantitative study at several urban blue spaces in four large cities in Western Germany, people reported a specific experience of and emotional bonding to water leading to a complex valuation of the place such as increased aesthetic experience and positive emotions. The evoked feelings effected a self-reported, profound restoration of the visitors to urban blue space (Volker, Matros, & Classen, 2016). According to other studies, blue space is also considered as a driver for physical activity (Halonen et al., 2014; Völker & Kistemann, 2011; White, Wheeler, Herbert, Alcock, & Depledge, 2014). The linear routing along the shore in blue areas with normally a clearly defined length promotes this form of exercise. The opportunities for potential health improvement provided by natural environments in urban areas are particularly important given the increasing cost of treating ill health (Buck & Gregory, 2013). Conversely, a species-rich site may prevent individuals from experiencing well-being if, as a result of its immense ecological value, access is restricted, or people feel that they are no longer able to access it. It is also possible that the mere knowledge of the existence of an aesthetically pleasing blue space within their local urban setting may in itself be enough for it to impact upon well-being, even if more tangible or visual forms of interaction with it were rare. Despite there being clear physical benefits to having a blue space nearby for example, cooling effects in urban heat islands (Gunawardena, Wells, & Kershaw, 2017) and in green space for mitigating air pollution with greater vegetation diversity (Vieira et al., 2018), evidence to support the idea of the just the knowledge of the existence of blue/greenspace having an effect on well-being, is lacking and requires further empirical study. At the same time however, encounters with biodiversity beyond these familiar contexts may be potentially unsettling for human well-being. In terrestrial systems, forests and woodlands are often viewed as places for recreation, relaxation and opportunities to connect with nature (Park, Tsunetsugu, Kasetani, Kagawa, & Miyazaki, 2010). However, this is unlikely to be a universal effect and may in fact represent a negative experience either through personal experiences or through negative portrayal of woodland in the media (Milligan & Bingley, 2007). Similarly, these concerns are shared with accessibility of certain blue spaces where previous experiences may influence how a particular blue space is perceived. The negative health impacts of exposure to flooding events can result in negative associations with residing near rivers (Fernandez et al., 2015). Furthermore, it is possible that a temporal dimension exists between how blue space may be utilized during the day and night. For example, a canal towpath or riverside may provide opportunities for recreation and physical activity during the day, but it may be argued that in certain circumstances, such as during darkness hours, these same places may be perceived as a threat due potential risks to personal safety and encountering antisocial behavior. The role of crime within green spaces has received limited attention (e.g., Kimpton, Corcoran, and Wickes [2017] but is suggestive of temporally and spatially-dependent factors as well as socio-demographics. Furthermore, the rhetoric of drowning risks and other dangers are often associated with accessing urban water bodies, thereby establishing them as negative components of a landscape.

The temporal nature of values placed upon biodiversity requires consideration, such as a perceived short-termism in the way that people view natural environments, with a tendency for individuals to be satisfied with present day levels of biodiversity, rather than aspiring to either levels attained in the past or to potential future gains ("shifting baseline syndrome",[Papworth, Rist, Coad, & Milner-Gulland, 2009]). Similarly, an increasingly urbanized global population may be becoming further detached from nature experiences ("extinction of experience" (Miller, 2005), resulting in deterioration of public health and well-being and an overall "disaffection toward nature" (Soga & Gaston, 2016). However, the perception of natural resource scarcity could both foster public demand for blue space preservation and increase its perceived value.

As has been suggested elsewhere there is often a mismatch between people's perception of, and actual, species richness (Dallimer et al., 2012; Hassall, 2014) (Figure 1), but there is increasing evidence that in some settings, peoples subjective perceptions of species diversity may reflect objective measures (Gunnarsson, Knez, Hedblom, & Sang, 2017). So, while people may not explicitly recognize biological diversity, there are aspects of it that may be appreciated in terms of well-being gains. Certain charismatic species (e.g., Kingfishers (*Alcedo atthis*), Dragonflies (Odonata)) may play an important role (e.g., McGinlay et al. (2017)) for individuals to connect with biodiversity in a tangible or emotional capacity. It should also be recognized that different urban blue space user groups may have greater knowledge of particular species and may be inclined to view their abundance more positively than other user groups - anglers for example, would likely be especially satisfied with increased abundance and diversity of fish or the presence of a particular species after a period of absence due to poor water quality (e.g., Atlantic Salmon (*Salmo salar*) (Bottom, Jones, Simenstad, & Smith, 2009)). However, the same may also be true where poor water quality may be relatively unimportant, but valuable in terms of recreation and for the regulating ecosystem services (e.g., flood alleviation) provided by urban rivers and ponds.

While particular species are likely to provide an important service for human well-being, more research is needed to examine causation, and to assess if and how these benefits are experienced by people from diverse social groups and at different stages of the human life course. While there may be some reluctance amongst ecologists to embrace the contribution to biodiversity of some non-native or invasive species, the addition of carefully selected charismatic species for example, water lily (*Nymphaea*) cultivars, could provide a potential compromise if it meant that the more "natural" biodiversity lying unseen below the water surface remains untouched.

Although some non-native (but noninvasive) species are often viewed positively from an aesthetic perspective and may indeed play a role in nutrient retention or bank erosion protection, during the summer months, their ecological value is debatable. Examples include Himalayan Balsam (*Impatiens glandulifera*) which dies back in winter months, leaving the river bank vulnerable to erosion (Greenwood & Kuhn, 2014). Ecologists may argue the case that non-native species should gradually be replaced by native species that perform the same functions. However, it should also be recognized that people's well-being may be bound up with the familiar sight and sound of particular (non-native) species for example, Canada geese (*Branta canadensis*) or Gray squirrels (*Sciurus carolinensis*), and that any intentional reduction of these species might be detrimental to human well-being if not undertaken sensitively and accompanied by appropriate forms of interpretation. Further to this, there is some evidence that suggests that non-native (but noninvasive) species may also contribute to biodiversity at a local scale (Schlaepfer, 2018).

It is clear that the role of non-native invasive species in contributing to biodiversity in urban areas also requires further investigation (Dures & Cumming, 2010) and remains contentious. Invasive species (those non-native species that have a negative impact on recipient ecosystems) can represent a significant challenge to maintaining urban biodiversity and effective intervention measures are required to control and manage their spread. New Zealand pygmy weed (*Crassula helmsii*) and Floating Pennywort (*Hydrocotyle ranunculoides*) for example, are adaptable to a variety of aquatic conditions making them two of the United Kingdom's most virulent invasive species (Collier, 2008). Therefore, the ecological and economic costs of failing to control their spread could be significant for delivery of certain ecosystem services. Furthermore, it is also quite possible that different perspectives of what constitutes a biodiverse water body, will vary between ecologists and some user - groups and therefore the relative role of native and non-native species for biodiversity and for human health and well-being is less clear. The role of education in alerting the public to the potential ecological issues associated with non-native species has long been debated. Public disengagement or detachment from nature, particularly amongst children, is complex and while it is receiving increased attention (Louv, 2009; Warber, DeHudy, Bialko, Marselle, & Irvine, 2015), relatively little is known about the most effective and appropriate ways through which education can and should be imparted (Novacek, 2008). Information on the relative merits of native and non-native species that is deemed didactic, judgmental or overly complex could therefore inhibit information sharing with the public. However, through carefully targeted educational initiatives (e.g., "Citizen Science" projects) demonstrating the importance of interconnections between key species, it might be possible for people to become re-familiarized with, and start to appreciate, the value of native species.

Recognizing the heterogeneous nature of blue space is also an important factor when trying to understand the relative benefits obtained from different types of urban blue spaces. Similar research across urban and rural green space has shown that different land cover types are linked to variation in self-reported health (Alcock et al., 2015; Wheeler et al., 2015). Increasingly this has also been recognized across the different types of urban blue space (ponds, lakes, canals, rivers, fountains) particularly in consideration of the important ecosystem services they provide (Völker et al., 2013). Furthermore, hypotheses suggesting an increase in biotic homogenization within urban green space is debated and has received increased attention

(McKinney, 2008). However, there remains a lack of evidence as to whether urban water bodies may experience similar effects.

3 | LINKING BIODIVERSITY WITH HUMAN HEALTH AND WELL-BEING

Ecosystem service assessments have sought to formalize an understanding of the complex interdependent relationship between the natural environment and human health and well-being (Daniel et al., 2012; Millennium Ecosystem Assessment, 2005). Much of this work has focused on the potential for biodiversity to regulate ecosystem processes and functions, and on the provisioning goods and services that ecosystems provide. Direct links between biodiversity and human health have been generally less explored, except in terms of how loss of biodiversity may impact on ecosystem functioning. One example is alterations of disease regulation, which has direct impacts on health in terms of causing changes in risk of disease (Keesing et al., 2010; Pongsiri et al., 2009). Human exposure to disease may be mediated through ecosystem change (e.g., urbanization) resulting in the creation of favorable conditions that were previously unsuitable for certain vector-borne diseases (e.g., malaria and tick-borne Lymes Disease, Patz et al., 2005). There is also some evidence that suggests that having greater species diversity provides a “dilution effect” (Ostfeld & Keesing, 2000) whereby diverse ecological communities limit the spread of diseases (Schmidt & Ostfeld, 2001) with the implication being, that with greater loss of biodiversity comes greater risk of disease transmission that threaten human, wildlife and plant health (Civitello et al., 2015). Other examples of the importance in biodiversity for human health have been described in studies that explore how greater vegetation diversity may result in green spaces being more diverse in their structure and function and thereby provide greater capabilities for mitigating the impacts of air pollution (Aerts, Honnay, & Van Nieuwenhuyse, 2018; Manes et al., 2016). While this may be important in urban settings, it should be acknowledged that many provisioning services are provided by extremely low diversity systems, for example, food production.

Although some evidence exists to suggest that biodiversity is supportive of positive health and well-being, others have concluded that data to support this assertion is limited (Cardinale et al., 2012; Lovell et al., 2014; Sandifer, Sutton-Grier, & Ward, 2015). With a few notable exceptions (e.g., (Dallimer et al., 2012), research to date has focused on the potential for biodiversity-related human health benefits in urban green space. While it is recognized that some of the issues raised in the urban green space literature may also be pertinent to urban blue space, it is clear that this is an area in which further research and understanding should be prioritized.

4 | INCREASING THE POTENTIAL FOR BLUE SPACE HEALTH AND WELL-BEING

Research has demonstrated a link between people's interactions with aquatic environments and their health and well-being with evidence emerging that blue space is amongst people's most preferred places for restoration and relaxation (White, Pahl, Ashbullby, Herbert, & Depledge, 2013). While most of this research has focused on coastal settings (Wheeler, White, Stahl-Timmins, & Depledge, 2012), a small but growing body of research suggests that urban freshwater bodies can protect health and support well-being through masking traffic noise (Jeon, Lee, You, & Kang, 2010; You, Lee, & Jeon, 2010), mitigating summertime temperatures (Völker et al., 2013), providing high levels of restorativeness (Thomas, 2015; White et al., 2010) (also see Korpela (2013) for further discussion of restorativeness), and providing spaces for improved physical activity, social interaction, and recreation (Thomas, 2015; Völker & Kistemann, 2011). Such health-related services, alongside other benefits such as flood mitigation and water quality enhancement, have been proposed as a key argument for the redefinition of global policies around smaller water bodies such as ponds, which are typically excluded from conservation policy (Hill et al., 2018).

Associations between people's interaction with natural environments and people's interest in, and knowledge of, its ecological worth has also been documented (Halpenny & Caissie, 2003). This is demonstrated in aquatic citizen science initiatives such as “Fixing Broken Rivers” and the “Anglers Riverfly Monitoring Initiative” (Riverfly Partnership, 2010). Importantly, most common forms of urban water bodies are used for recreation, physical activity, and relaxation that are unlikely to pose significant pressure on biodiversity and ecosystem functioning as long as the ecosystem is sufficiently resilient. While this assertion has significant implications in terms of maximizing both biodiversity and health and well-being outcomes, it also raises several important questions relating to perceptions of different types of urban water bodies, their access, and use.

First, as with much of the literature on the salutogenic (health-promoting) potential of green space, knowledge on the health and well-being impacts of blue space tends to be underpinned by an assumption that where people have such settings nearby they will use them. Research within this area also tends to be based on the experiences of those already using such spaces, paying far less attention to those who are not. This is an important oversight, not only in terms of data bias, but also from the perspective of health inequalities. An emerging body of research within the social sciences is beginning to acknowledge the ways in which urban natural spaces can become embedded with a range of sociopolitical associations and narratives that code them and their usage in particular ways in relation to factors including race (Byrne & Wolch, 2009), age, and body shape (Thomas, 2015). The result, in some cases, is racial differences in the benefits accrued through proximity to green space (Dadvand et al., 2014). While better understanding of these issues is clearly not of direct relevance to aquatic biodiversity per se, understanding why people avoid such spaces does have potentially important repercussions both in terms of well-distributed health-related ecosystem services and in maximizing the potential for diverse groups of people to place value upon the biodiversity of urban water bodies.

A second, related question concerns the distribution and accessibility of good quality blue space. Literature on urban green space has emphasized how people living in areas with low socioeconomic status often have relatively poor access to high quality natural environments (Mitchell & Popham, 2007). It is likely that this is also the case with urban blue space, although research is needed to confirm this assumption. Accessibility is a key consideration if health benefits are directly obtained from the ability to use a blue space for an activity (Völker et al., 2018). If, however, health and well-being gains for some groups are obtained from views of urban water bodies (Nutsford, Pearson, Kingham, & Reitsma, 2016), rather than use, physical access may be less important. If this is the case, it again raises important questions over the potential for urban freshwaters to provide universal health and well-being benefits. The likelihood (probability) of people connecting in a positive way may be unaffected, but the opportunity for them to be exposed may be lower. This also creates an inequality and in this case, an injustice in terms of access and well-being benefits.

5 | VALUING URBAN WATER BODIES

Economic assessments have demonstrated the value accorded to blue space recreation. Angling for example, is thought to generate around £3.5 billion a year in economic activity in the United Kingdom (Angling Trust, 2012). Research has demonstrated that people tend to place a high economic value on residential and business locations near blue space (Sander & Zhao, 2015) and this value is typically reflected in property and land prices. However, hazards such as flooding or the presence of aquatic disease vectors such as mosquitoes mean that assessing the risks and disbenefits associated with urban blue space also forms an important component of any valuation. Cost–benefit analysis (CBA) is used routinely in the decision-making process to evaluate the monetary values of risks and benefits, and to compare these to costs of particular interventions, including actions to improve water quality under the Water Framework Directive (Hanley & Black, 2006). However, cost–benefit analysis is often criticized as it uses discounting, which has implications for intergenerational equity. CBA also involves placing monetary values on risks and benefits—and for certain impacts in freshwater ecosystems (e.g., biodiversity) such values may not exist or not be fully understood. Multicriteria analysis can allow decision makers to more explicitly consider impacts which are hard to quantify in monetary terms (Kiker, Bridges, Varghese, Seager, & Linkov, 2005). The multiple uses of urban water bodies may lead to conflicts regarding perspectives and priorities—a blue space with high recreational value may be deemed to be of low ecological value and vice versa. The valuation of cultural ecosystem services and well-being relating to urban freshwaters are attracting increasing interest (e.g., recreational fishing, Villamagna, Mogollón, & Angermeier, 2014) and socioecological systems (Vollmer et al., 2018) but more work is needed to ensure research is translated into practice.

The ability to quantify nonmarket valuations may be challenging and may also be influenced by the media, and by historical and cultural associations. Contemporary media representations of urban blue space may often be negative, portraying them as dangerous elements within the landscape due in large part to the spate of flooding incidents in recent years (Valencio & Valencio, 2018). There is also a clear need to incorporate local priorities into the valuation of services and disservices, since the importance of ecosystem services will vary dependent upon local needs. Research is needed into the optimal spatial scaling of valuation exercises to maximize benefits across populations.

Types of green space, particularly in the English countryside, have deeply ingrained and often romanticized associations with national heritage and has formed the inspiration for poets and storytellers throughout the ages's Blake's (1804). Now famous "green and pleasant land" has become synonymous with the English countryside (Alcock et al., 2015). However, many of these culturally valued landscapes, such as sheep-grazed upland moors and lowland pasture divided by dry stone walls, are ecologically depauperate compared to the patchwork of forests and meadows that developed following the end of the Pleistocene. Perhaps as a result, whether these culturally valued landscapes are species rich or poor is not overtly acknowledged or understood. Although a range of flora and fauna have featured in well-known literature and art and it is likely that this has had some influence on perceived cultural value. The potential for exploiting cultural and historical associations to increase the valuation of urban blue space biodiversity has, as yet, received relatively limited attention. Historically, much urban blue space has its origins in functional roles such as transportation of goods through river and canal networks and drainage. Ponds and lakes have often been incorporated into the design aesthetic of many Victorian public parks and gardens (Jordan, 1994), with little priority given to the biological diversity of the space. Importantly, this may represent an opportunity to engage those people who already have strong emotional or cultural attachments to a particular blue space and would perhaps be more invested in promoting biodiversity and appropriate management of the site. Forms of interpretation could also be used to demonstrate to people how previously sterile, or utilitarian aquatic environments could be transformed into a biodiverse blue space and that this knowledge and the "sense of place" engendered through this could in turn have positive impacts upon well-being. This may be achievable across a range of blue space environments, and that in cases where regeneration was relatively recent (e.g., urban canals; Clapham Common Ponds, London) could also help foster a sense of civic pride and ownership.

6 | DEVELOPING MIXED METHODOLOGIES

A diverse range of ecological, epidemiological, and social science valuation methods are utilized across disciplines and sectors. While practitioners are increasingly seeking to address a range of amenities through aquatic management, most urban freshwaters research to date has focused either on ecological functioning, or on human health and well-being, with limited studies examining both (Gascon et al., 2015; Völker & Kistemann, 2011). An important aspect of combining these two agendas would be to provide rigorous evidence isolating and demonstrating a causal link between blue space biodiversity and health and well-being. This would need to encompass assessment of aquatic condition (defined via species richness or ecological status), and the health and well-being benefits associated with these biodiversity metrics. However, the nature of the evidence required to unpick and explain the proximal and distal pathways shaping any such relationship may present some methodological challenges.

Traditional monetary value-based measures of alternative health outcomes also provide a means to begin to understand some of the risks and benefits associated with urban aquatic biodiversity and urban blue space more broadly (Himes-Cornell, Pendleton, & Atiyah, 2018). Mace, Hails, Cryle, Harlow, and Clarke (2015) suggests that the knowledge of risks affecting natural capital in urban areas is poor and that freshwater assests in urban setting are at high risk (Mace et al., 2015). Assessing health benefits from urban blue space within a risk framework may provide further opportunities to assess the challenges of measuring/quantifying ecosystem services of urban freshwaters. For example, the Health Economic Assessment Tool (HEAT) has been developed to value the health benefits of cycling and walking in terms of reduced mortality and has been used to value recreational uses of the Forth and Clyde and Union canals in Scotland at £6.4 m (Canning, Leitham, & Connolly, 2011).

Methodological challenges also exist with evaluating health outcomes. Many health economists prefer quality adjusted life years (QALYs) as a measure of benefit instead of using monetary values of health outcomes. The use of QALYs enables the combination of multiple health benefits into one index, which can be used for cost-effectiveness analysis to facilitate the allocation of resources. Exploring alternatives to monetary valuation (including multi criteria analysis) may be particularly important when considering the less tangible cultural ecosystem services provided by urban freshwaters. The aesthetic and spiritual qualities of these ecosystems are less amenable to the application of a monetary valuation method, yet are likely to present a significant component of the salutogenic effects of freshwater biodiversity (Kenter et al., 2015).

Techniques such as systematic review and meta-analysis, analysis of large-scale longitudinal and panel data, qualitative interviews, focus groups, primary biological and ecological data collection, and a range of participatory methods are currently used successfully to help inform understandings of environment—human relations (e.g., Bell, Phoenix, Lovell, & Wheeler, 2015; Schwarz et al., 2017). Mixed methodologies using these techniques could also help to elucidate particular exposure-outcome pathways to provide more specific insight into the relative role of biodiversity. Other techniques that have potential for this include eye tracking and apps that focus on recording people's physical and emotional status while in particular environments (e.g., MacKerron & Mourato, 2013).

One potential barrier to the effective use of mixed methods across multiple disciplines and sectors is a perceived expectation within the public health sector for research to be considered sufficiently "valid" to be driven by a fairly narrow range of experimental data collection techniques, such as those resulting from randomized controlled trials (RCTs). Although, there has been some movement toward questioning RCTs as a sole basis for decisions in the health sector and incorporating other forms of evidence (Frieden, 2017). Expanding this mind set to consider the validity of a wider range of evidence types was deemed to be important if insightful understanding of biodiversity's role in health and well-being is to be achieved.

The life-grid approach (Berney & Blane, 2003) is a useful technique used to examine biographical exposure data, could be applied in this context to assess the role of urban aquatic biodiversity for health and well-being. While not commonly used in environmental research, this approach offers opportunities for examining the ways that people perceive and "place" particular spaces, emotions, and events within broader social, economic, spatial, and temporal contexts. Being able to prompt discussion on urban blue space biodiversity across significant moments of the life course or at key development periods in children would therefore likely elicit useful information that could feed in to inform a larger methodological body of work.

Case studies showcasing blue space restoration impacts on ecological functioning and on community health and well-being were felt to hold particular traction with policy makers. There are examples in terrestrial systems that show ecosystem restoration activity has a positive effect on preventing the spread of some vector-borne diseases (Speldewinde, Slaney, & Weinstein, 2015) and in urban aquatic environments the use of nature-based solutions to manage flood risk (Bauduceau et al., 2015). However, for researchers to be in a position to successfully undertake this kind of "natural experiment" requires prior knowledge that the intervention was taking place and adequate notice to undertake baseline work. The complexity and uncertainties involved in ensuring any such intervention is initiated and seen through to completion, requires that Research Councils and other funding bodies be prepared to take risks to fund this type of innovative work. It is also important to consider the temporality of health and well-being effects from this type of intervention. For example, while the simple knowledge that an intervention is imminent may positively influence health and well-being for some people, others may not feel the benefits until several months or even years after it had been introduced.

Uncoupling green and blue space research and practice requires further discussion. Although there are exceptions, most urban blue space exists alongside, and within the wider context of, some form of green space (e.g., parks, towpaths). In some cases for example, fish, it is clearly possible to separate biodiversity components of blue and green space. However, in other cases (e.g., water birds), this is more difficult, and if taken more broadly to consider food webs, may in fact be unhelpful. A further scale of organization that requires a different management approach is that of the catchment, where each city sits within a particularly hydrological zone and may be subject to the processes that occur elsewhere in that catchment. A case study in Leeds in the United Kingdom, demonstrates where a small, steep catchment leads to flooding through rapid movement of water into the cities. Hence, urban landscape managers prioritize maximizing flood alleviation and mitigation in urban water bodies above other considerations such as health and biodiversity. Such prioritization of services no doubt follows a hierarchy of urban management needs, where the integrity of the built environment is the most important and biodiversity is less so. In order to balance competing priorities in cities, there may need to be action elsewhere in the catchment to free up resources to optimize multiple ecosystem services. Conversely, attempting to manage individual water bodies in isolation without recognizing their functional connectivity and interdependence is likely to be a waste of resources and a missed opportunity (Hill et al., 2018). This issue of flow and connectivity can bring hydrometeorological risk, but can also bring opportunity. Through the removal of dams and other obstructions, important elements of biodiversity such as otter and salmon can return to urban rivers (Dorobek, Sullivan, & Kautza, 2015). However, that river system needs to be managed as a whole as damage in one stretch will effectively fragment the network even if that damage does not spread. One example of catchment-based solutions to urban flooding is the current plan to reforest large areas of the north of England (and particularly the land surrounding large conurbations) as part of a "National Forest." Similarly with human health and well-being; while it may be possible to attribute health benefits brought about via physical activity to particular blue or green settings, disentangling the impacts of blue and green space exposure to feelings of well-being and restoration at different scales would be more complex. Recognizing and understanding the interlinked relationship between blue and green space, and the connectedness of the wider landscape, is therefore vital for effective management.

Blue/green space forms a continuum along which specific habitat types exists (e.g., riparian zone). However, ecologically and, to an extent, in terms of health and well-being, urban aquatic ecosystems are distinguishable from urban green space. As such, it is vital that these qualities are recognized and that the features that differentiate blue space do not become engulfed within broader, often homogenized, green space definitions. From an effective resource and land management perspective, incorporating ecological ideas of connectivity (Beninde, Veith, & Hochkirch, 2015) and effective gene flow to promote diversity between blue and green space, is an important consideration. Further to this the benefits of highly connected patches may also bring with them the potential risk of disbenefits, such as the spread of invasive species and pathogens (Millins et al., 2017). Consideration of aquatic biodiversity at multiple scales from local to catchment level, with blue spaces viewed as a network, or as corridors for species movement rather than as individual, isolated entities is increasingly being recognized as an effective approach. The catchment-level approach employed by the South East Rivers Trust, United Kingdom, for example, encapsulates the idea of crossing potentially complex and contradictory administrative boundaries.

7 | CONCLUSION

By 2050, an additional 36 million people will reside in urban areas across Europe (United Nations, 2014). The growing evidence base demonstrating positive associations between the natural environment and health has begun to focus on the role of water, particularly in urban areas. Urban freshwaters may be critical to the development of adaptation and mitigation strategies to address the negative health and environmental impacts of urbanization and climate change. Four broad research gaps have emerged, representing opportunities to promote urban aquatic biodiversity for health (Figure 1). At the same time, however, areas of potential conflict between the agendas of research, policy, and practice exist, suggesting a need for more open and accessible dialogue between policy, practitioners, and researchers to fully optimize opportunities to enhance and promote urban aquatic biodiversity for health more effectively. Furthermore, a unified approach to our understanding of biodiversity is required and the priority outcomes associated with this across disciplines and sectors identified.

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CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

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