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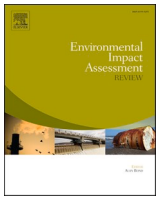

Freshwater blue space design and human health: A comprehensive research mapping based on scientometric analysis

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ABSTRACT

Water is a critical element of human existence and has shaped cities for centuries. In urban environments, water provides multiple ecosystem services and is an important element in the design of urban environments. Next to the many qualities and services provided by water, recent research indicates that exposure to freshwater blue space also enhances human health and wellbeing. However, health benefits are often not or implicitly taken into account in the design perspective.

This research aims to provide a systematic overview of the available body of knowledge regarding the relationship between freshwater blue space, health, and design. This study first proposes a bi-directional conceptual framework connecting health evidence with design practice. And then, scientometric analysis is employed to review 1338 research articles on freshwater blue-health research. The results show that the number of articles in this area is increasing yearly, attracting more and more disciplines and stimulating interdisciplinary collaboration. Freshwater blue-health research is broadening to emphasize usage and experience, psychological advantages, and particular demographics, which provides a solid basis for future design research. At the same time, it becomes clear that there is a strong demand to develop adaptive design knowledge that integrates the available health evidence and operationalizes it in healthy freshwater blue space design. This paper could help researchers understand the current research progress and future research directions, as well as facilitate multiple applications of health evidence by practitioners.

1. Introduction

With the prevalence of chronic lifestyle-related diseases, people's attention to health issues is increasing globally. Rapid urbanization has been recognized as the main factor resulting in these health issues (Fisher et al., 2017). Along with the expansion of the global population, it is estimated that over 60% of the world's inhabitants will live in urban areas by 2030 (Rydin et al., 2012). In this context, it is essential to meet the requirements of the growing global population for healthy living in urban environments, which are also relevant to sustainable development objectives (UN General Assembly, 2015). Therefore, understanding the urban environment from a holistic health perspective and conducting health impact assessment (HIA) are becoming increasingly important, which provide a wide range of social, economic and environmental benefits (Bhatia and Wernham, 2008). The diverse health benefits of contact with natural environments have been increasingly discussed worldwide, especially in urbanized contexts (Hartig et al., 2014). Natural environments or natural-based interventions could be regarded as a practical approach for coping with non-communicable diseases in urban areas (Hunter et al., 2017). While natural environments have become an increasingly important part of global public health and urban planning policies, the potential for health benefits of blue space has received less attention than green space. Even compared to blue space's other functions and ecosystem services, health benefits have not received enough attention. Over the past few years, a growing body of research has recognized this issue (Britton et al., 2020; Grellier et al., 2017; Higgins et al., 2019; McDougall et al., 2020; Smith et al., 2021; White et al., 2020). While the total amount of research is still limited, they provide more and more evidence that exposure to blue space could promote human health and wellbeing in multiple ways (Gascon et al., 2017; Grellier et al., 2017; McDougall et al., 2020; Völker and Kistemann, 2011; White et al., 2020).

Although the interaction between water and human health has been discussed for decades, water has always been affiliated with green space

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and has not received enough attention (Grellier et al., 2017; Solomon, 2010). In recent years, with the establishment of several large projects, including the BlueHealth Programme (Grellier et al., 2017), the Marine and Coastal Access Act 2009 (UK Government, 2009), and Blue Gym activities (Depledge and Bird, 2009), the health-water relationship study has re-attracted researchers' attention from multiple disciplines, including human geography, public health, urban design, and landscape architecture (Grellier et al., 2017). During the early stages of health-water research, several terms were used to describe outdoor water environments, including blue infrastructure (Haase, 2015), aquatic environment (Jones et al., 2004), and surface waters (Völker and Kistemann, 2011). These terms mostly originate from disciplines not closely related to recent health-water research. For instance, blue infrastructure is a broad concept that includes water supply systems with less connection to health-water research. As McDougall et al. (2020) pointed out, health-water research has shifted from a by-product of therapeutic landscape and environmental health toward an established academic research field. Alongside the rapid development of health-water research, the term 'blue space' has emerged and been used as a common definition for outdoor environments associated with water (Gascon et al., 2017).

In general, blue space could be divided into freshwater blue spaces and coastal environments (McDougall et al., 2020). There are considerable differences in physical and hydrological properties, as well as people's perception and usage. Existing research on the health benefits of the coastal environment has yielded relatively robust outcomes compared with freshwater blue space, partially due to the fact that coastal environments cover a much larger area across the globe (de Bell et al., 2017). Positive effects of exposure to coastal environments on general health (Garrett et al., 2019; Gascon et al., 2017) and mental health (Dempsey et al., 2018; White et al., 2021) have been identified and summarized, while similar studies on freshwater blue space are still limited. Additionally, since the 1980s, waterfront rejuvenation has become a growing trend aimed at increasing access to primarily freshwater blue space. Therefore, the health benefits of freshwater blue space, an important spatial component of the urban environments, deserve attention and summary (Desfor and Jørgensen, 2004; Völker and Kistemann, 2011). Although combining freshwater and coastal blue space is suitable for addressing specific problems to some extent, it is challenging to summarize conclusions specifically connected to freshwater blue space (McDougall et al., 2020). Moreover, the transferability of these broader conclusions requires careful consideration, particularly when applied directly to the decision-making and design process.

In response to the identified health benefits, natural environment provision has been regarded as an effective approach for creating a healthy urban environment in several policy documents (UN General Assembly, 2015; WHO, 2013; WHO Regional Office for Europe, 2012). As a critical component of the urban natural environments, freshwater blue space is attracting increasing attention (Braubach et al., 2021). However, this attention mainly focuses on the provision of freshwater blue space rather than on the quality of those blue spaces. Spatial design is a core activity in landscape architecture and its related disciplines, aiming to provide solutions for urban and rural areas as well as projects such as parks, gardens and squares, or to develop potential by creating conditions for spatial, ecological and social development (Nijhuis and de Vries, 2019). It is one of the most direct approaches to improving the quality of the urban environments, including freshwater blue spaces. It can provide designers with detailed guidance on the spatial attributes needed to tackle lifestyle diseases (Douglas et al., 2017). Therefore, it is necessary to accurately position spatial design in freshwater blue-health research in order to generate a higher cost-benefit ratio in health services and reduce future health costs through this non-clinical environmental intervention (VanLare and Conway, 2012). As Rydin et al. (2012) pointed out, design professionals should actively communicate with people responsible for public health and focus on practical design processes through project experimentation rather than linear or cyclical schemes to promote a health-oriented urban environment. For clarity, the term 'design', referring to spatial design, is consistently used throughout this article.

Currently, only limited publications mentioned and reviewed the relevant evidence from freshwater blue-health research (McDougall et al., 2020; Vári et al., 2022). Specifically, Vári et al. (2022) took a broader view and explored the relationship between ecosystem services and freshwater systems. McDougall et al.'s (2020) research held a similar topic to this research. They adopted a narrative method to discuss some critical issues in freshwater blue-health research, with a particular focus on the measurement of freshwater blue space exposure. However, their research has paid little attention to incorporating health benefits into freshwater blue spaces from the action side, and spatial design has not received much attention as a direct and practical approach. Therefore, a comprehensive overview of the current status of freshwater blue-health research and its relationship to design could not only provide practical support for the establishment of healthy freshwater blue spaces and even broadly healthy cities, but also provide the methodological basis for the development of HIA and comprehensive EIA of freshwater blue spaces.

This research addresses the above issues by developing the conceptual framework, analyzing and distilling a large number of publications on freshwater blue-health research, and reflecting the outcomes from the design perspective. Specifically, the objectives of this research are to (1) propose a conceptual framework connecting freshwater blue space design and human health based on the existing models, (2) conduct a scientometric analysis of the state of the art knowledge on freshwater blue-health research with a particular emphasis on the role of design, and (3) summarize the trending topics and vacuum among current research by incorporating the conceptual framework and scientometric analysis results.

The paper is organized into the following sections. In section 2, a conceptual framework linking freshwater blue space design and human health is presented. Section 3 introduces the data extraction and methodology of scientometric analysis used in this study. Section 4 gives a brief overview of current freshwater blue-health research and identifies the prevailing themes found within this body of work. In section 5, several trending topics are recognized and discussed according to an in-depth exploration of the scientometrics analysis results. The main gap in current research is pointed out based on the framework and analysis results in section 6. In the end, the conclusions are organized, and future studies are suggested.

2. A framework linking freshwater blue space design and human health

To assist in organizing the available evidence, locating the positions of several key themes, and identifying the current research gap, a conceptual framework linking freshwater blue space design and human health is proposed. This framework is based on several previous models (Fig.1). First, based on Markevych et al.'s (2017) and Hartig et al.'s (2014) frameworks, this research extends the main pathways linking green/blue space and health into freshwater blue space and health, including a) improving ambient physical environments; b) enhancing physical activities; c) benefiting psychological outcomes; and d) promoting social interaction. Second, from White et al.'s (2020) model, since these four pathways are all derived from exposure and contact of freshwater blue space, the existing evidence that influences people's exposure or contact to freshwater blue space will be collected and summarized by reviewing current research (e.g. living closer to freshwater blue space may have the great possibility to contact it). Next, this evidence can be translated into design concepts that could be implemented in freshwater blue space design (e.g. living closer to freshwater blue space can be translated into the design concept 'residential accessibility'). Finally, according to the design research model proposed by Nijhuis and de Vries (2019), these health-related design concepts could be transformed into practical-reproducible knowledge through design

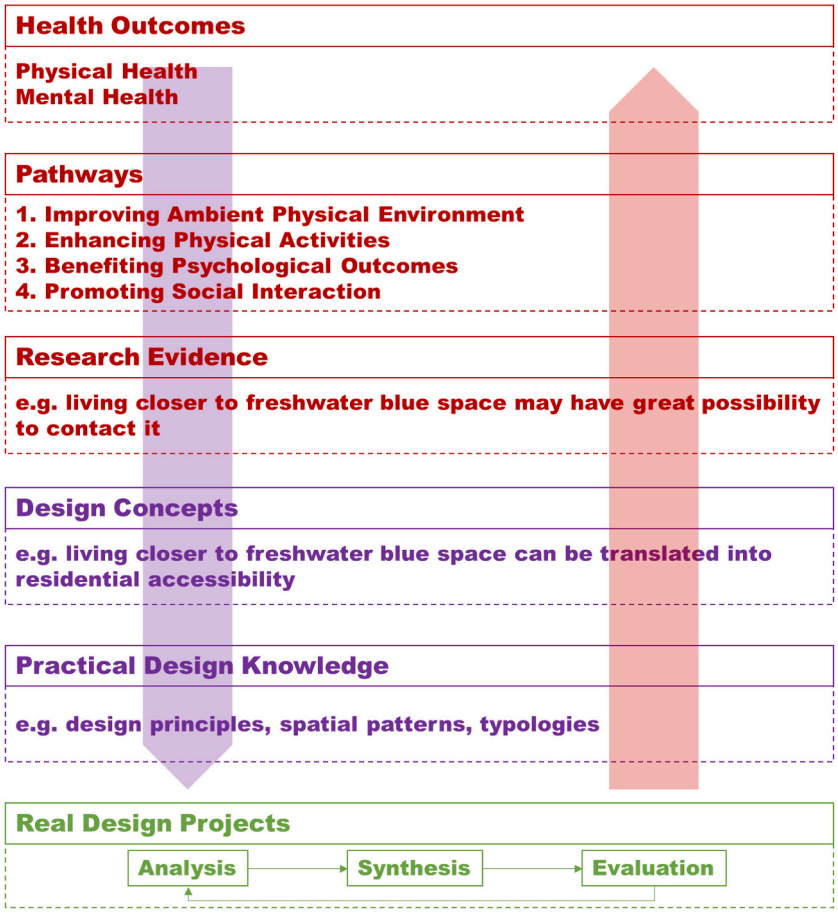

Fig. 1. A framework linking freshwater blue space design and human health.

exploration. And this practical knowledge then can be adapted and applied in future real freshwater blue space design projects.

Action-oriented connections between freshwater blue space design and human health are established through this six-step framework. As well as extending and introducing several previous frameworks to freshwater blue-health research, this new framework makes four additional contributions. First, inspired by Andersson et al.'s (2019) work, the framework can be regarded as a two-way dynamic process rather than linear with only one direction. As mentioned above, the interpretation of the framework begins with health evidence and ends with practical design knowledge and project practice. On the other hand, this framework can be interpreted from below. Rich project practices will provide the thinking basis and input for refining new health evidence. Second, the framework offers practical methodological support for integrating health evidence into the freshwater blue space design process. Previous studies mainly focused on the health side by providing more evidence on illustrating four main pathways rather than the design or action side. Thirdly, given the evaluative nature of the framework, it can provide the basis for constituting HIA and EIA. The design concepts translated from research evidence could be regarded as indicators to assess the health effects of freshwater blue spaces. Moreover, design knowledge can be used as a reference of practice to assist in integrating HIA and EIA into the design process, which has attracted growing attention (Fischer et al., 2021). Finally, the framework can be used to guide not only the transformation and application of health evidence in the freshwater blue space design, but also to inspire additional studies that actively apply health evidence in the design of other natural environments to shape healthy cities (Shanahan et al., 2015).

3. Methods and materials

3.1. Scientometric analysis of freshwater blue space design and health

Scientometrics offers a quantitative analysis of all features of scientific literature, which is generally used to identify knowledge structure, scientific contributions, research developments, and emerging trends in the research domain (Rawat and Sood, 2021). In scientometrics, knowledge mapping is the main technique to facilitate knowledge access and reveal the structure through visualization (Shiffrin and Börner, 2004). With the rapid technology development, it is possible to analyze a large amount of literature and data through software programs and visualize the results. However, as an emerging research field, no study in the freshwater blue-health field has comprehensively analyzed its conceptual underpinnings by knowledge mapping. As a result, this study relies heavily on scientometric analysis to gain a better understanding of the current freshwater blue-health research status and to discuss its relevance with design. Fig.2 describes the process of the methodology using several scientometric analysis tools.

3.2. Data collection

Web of Science (WoS) is a platform that provides access to several databases containing complete citation data for various disciplines, including natural science, social science, the arts, and the humanities. Web of Science Core Collection (WoSCC) is a carefully selected WoS database that provides high-quality, credible information and is a valuable source for scientometric analysis (Azam et al., 2021). The Science Citation Index Expanded (SCI-E), Social Sciences Citation Index (SSCI), Arts & Humanities Citation Index (A&HCI), Conference

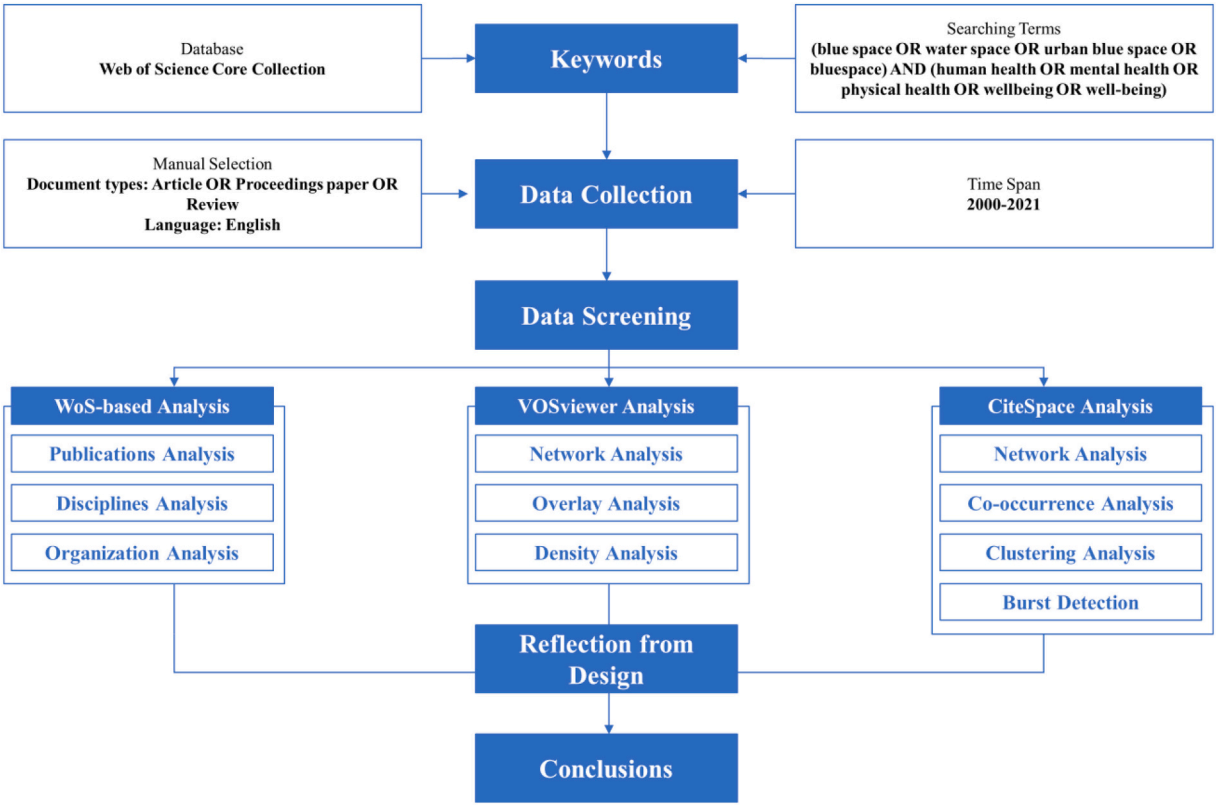

Fig. 2. The flow diagram for scientometric analysis.

Proceedings Citation Index- Science (CPCI-S), Conference Proceedings Citation Index-Social Science & Humanities (CPCI-SSH), and Emerging Sources Citation Index (ESCI) databases were selected as data sources for current research. Data were extracted on April 24, 2021, from the online library of Delft University of Technology (TU-Delft), the Netherlands. The search terms were TS = (blue space* OR water space* OR urban blue space* OR bluespace* OR freshwater blue space*) and TS = (human health OR mental health OR physical health OR wellbeing OR well-being), and the time span was set from 2000 to 2021. The articles, reviews, and proceedings, published in the English language were selected. Finally, 1338 documents were retrieved in plain text with a complete record, including cited references for further analysis.

3.3. Analysis methods

3.3.1. VOSviewer and CiteSpace Analysis

VOSviewer and CiteSpace, the most prevailing and leading software programs, are used in this research to conduct scientometric analysis. VOSviewer and CiteSpace are both Java-based software programs used to create coloured maps from bibliographic data and visualize and dig the intrinsic meaning of the maps. In the present study, three kinds of keywords-based visualizations from the VOSviewer were performed to gain a direct understanding of the research field, including network visualization, overlay visualization, and density visualization (Waltman et al., 2010). Each map emphasizes and conveys different information. Specifically, network maps represent the major research clusters among current bibliometric data, while density maps provide a quick overview of major areas in the scientometrics network. In addition, the overlay maps can be used to show the research development over time. On the other hand, the novelty of CiteSpace lies in the deep mining of the co-citation and co-occurrence data of specific documents. Co-citation analysis (co-cited reference clusters) and co-occurrence analysis (co-occurring keywords networks and clusters) can reveal the critical keywords in papers, as well as the trending topics and concepts of the whole research field (Zhang et al., 2020). Moreover, keywords-based burst detection analysis was used to identify research frontiers among current publications.

Based on the advanced functions and extensive applications of VOSviewer and CiteSpace, a visualized analysis of freshwater blue-health research was carried out. The obtained data was visualized in VOSviewer (1.6.16) and Citespace (5.7.R4) with the following procedures, respectively. First, 1338 documents with complete records and cited references obtained by data collection were used as input. Second, the required parameters in each software program were adjusted, and the analysis was conducted. The detailed parameters of each program are shown in Tables 1 and 2.

3.3.2. Web of Science (WoS)-based investigation

Web of Science (WoS) platform not only provides access to multiple databases for acquiring citation data, but also contains fundamental analysis tools for the searching results, including analysis of publication numbers, organizations, research fields, etc. These tools allow researchers to briefly and preliminarily overview the searching results through various diagrams or charts.

Table 1
Parameter of CiteSpace.

No.	Parameters	Definition
1	Time slicing	Year span from 2000 January to 2021 December, per slice for one year
2	Term source	Title, abstract, author, keywords
3	Node type	Author, institution, country, keyword, reference
4	Links	Default
4	Selection criteria	Top 10%
5	Pruning	Pathfinder and pruning sliced networks
6	Visualization	Cluster view-static and show merged network

Table 2
Parameter of VOSviewer.

No.	Parameters	Definition
1	Extraction fields	Title, abstract
2	Counting method	Full counting
3	Minimum occurrences	10
4	Selected terms	725

4. Preliminary explorations of scientometric analysis

4.1. Overview of the freshwater blue-health research

4.1.1. Number of articles published

Fig. 3 shows the number of documents in freshwater blue-health research between 2000 and 2021 in the WoSCC database. At the initial stage, this area did not receive much attention among scholars, and only a small number of documents were published between 2000 and 2004. However, the research field increasingly attracted attention after 2005, and the number of publications gradually increased. Although there were fluctuations in 2008, 2011, and 2014, the number of documents increased rapidly from 19 to 250 from 2008 to 2020, with an annual growth rate of 23.96%.

4.1.2. Distribution of research disciplines

Freshwater blue-health research is a multifaceted issue encompassing several disciplines. Table 3 lists the top 10 fields covered by the research with the most papers in the WoSCC database. Among 1338 documents, 425 came from environmental science, 212 from public environmental occupational health, and 175 from environmental studies, accounting for 31.76%, 15.85%, and 13.08%, respectively. In addition, water resources, urban studies, ecology, and geography play important roles in understanding the relationship between freshwater blue space and health.

Environmental science and environmental studies accounted for a large proportion of freshwater blue-health research, reflecting the importance of both natural and social science in this research area. In addition, according to the analysis of authors and organizations, there have been a number of publications in recent years funded by the BlueHealth project, which promotes collaboration between interdisciplinary researchers (Grellier et al., 2017). The establishment of this multi-disciplinary research project indicates the growing interest of policymakers in better understanding the relationship between blue space and health and then applying this knowledge to policies and design processes. Although environmental sciences, urban studies, and geography partially contain some studies from design or policymaking, it is not always the case. Furthermore, most of the studies were conducted in Western developed countries. Therefore, obtaining more evidence from developing countries, especially countries in Asia and Africa with a higher pace of urbanization, is necessary.

Table 3
Discipline distribution of documents (Top 10).

No.	Fields	Quantity	Proportion
1	Environmental sciences	425	31.76
2	Public environmental occupational health	212	15.85
3	Environmental studies	175	13.08
4	Water resources	101	7.55
5	Urban studies	96	7.18
6	Ecology	85	6.35
7	Geography	80	5.98
8	Engineering environmental	78	5.83
9	Green sustainable science technology	67	5.01
10	Geosciences multidisciplinary	58	4.34

4.2. Prevailing themes in freshwater blue-health research

4.2.1. Main research keywords

Keywords are the critical refinement, core contents of the research paper, and the analysis of keywords can provide an overview of the main topics related to freshwater blue-health research. Table 4 lists the top 15 occurring keywords associated with this research field. These keywords can be categorized into three main themes, including mechanisms linking freshwater blue space and human health (e.g. physical activity, ecosystem service), different health benefits of freshwater blue space exposure/contact (e.g. mental health, impact, benefit, human health), and the relationship with other global challenges (e.g. climate change, biodiversity).

Mechanisms linking the natural environment and human health have attracted considerable attention among research communities worldwide. The studies regarding green space have concluded three main health-promoting pathways, including reducing harm (mitigation),

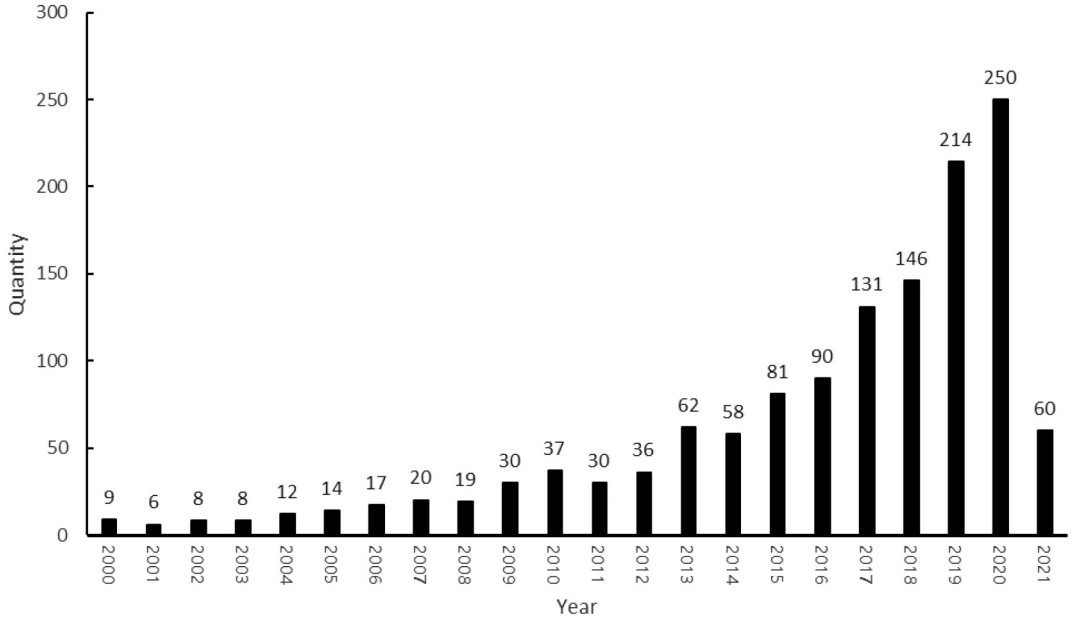

Fig. 3. Annual distribution of the studies.

Table 4
Top 15 critical keywords ranked by frequency.

Ranking	Keywords	Frequency	Year	Centrality
1	Water	273	2001	0.12
2	Green space	199	2011	0.03
3	Health	193	2002	0.10
4	Physical activity	170	2008	0.06
5	Environment	118	2009	0.02
6	Mental health	116	2001	0.03
7	City	104	2010	0.04
8	Exposure	103	2010	0.09
9	Impact	95	2008	0.02
10	Ecosystem service	86	2013	0.01
11	Space	80	2007	0.06
12	Benefit	76	2009	0.09
13	Climate change	67	2010	0.05
14	Human health	64	2013	0.00
15	Biodiversity	54	2007	0.07

restoring capacities (restoration), and building capacities (instoration) (Markevych et al., 2017). As mentioned in section 2, there are four main pathways linking freshwater blue space and health based on the existing research outcomes, including improving ambient physical environments, enhancing physical activities, benefiting psychological outcomes and promoting social interaction. Although the main pathways are widely recognized, more evidence is still needed to show their applicability in different contexts.

From the framework in section 2, health outcomes of freshwater blue space exposure can be seen as the higher step or outcomes of mechanisms that link exposure and health. It has been widely discussed in epidemiology and public health. True experiments, natural experiments, and observational studies are adopted to examine and broaden the health outcomes of freshwater blue space exposure both physically and mentally (Frumkin et al., 2017).

Freshwater blue space can provide various ecosystem services and always be connected to coping with many global challenges (Haase, 2015). Many studies attempt to integrate the health benefits of freshwater blue spaces with other ecosystem services to comprehensively address global challenges, including health issues, biodiversity loss, climate change, etc. (Vári et al., 2022). However, it is worth noting that existing studies have identified the complex interactions among different ecosystem services, including synergies and trade-offs (Haase et al., 2012; Hossu et al., 2019; Qiao et al., 2019). Therefore, future freshwater blue-health research could uncover such interactions between health benefits and other ecosystem services and consider them when implementing projects to make more efficient use of freshwater blue space.

While some keywords strongly connect to space, only a few are directly tied to design. There are three possible reasons for this phenomenon. To begin, not all research results relating to design are included in the WoSCC database, rather, they are shared via professional design magazines and reports. Second, most current research is devoted to explaining the relationship between freshwater blue space and human health, attempting to establish causal relationships (Gascon et al., 2015). As a result, it will take time to turn this evidence into practical knowledge for design. Third, freshwater blue space and health research necessitate cross-disciplinary collaboration (Rydin et al., 2012). The absence of designers in the debate exacerbates the scarcity of findings immediately applicable in design.

4.2.2. Research frontiers

Burst detection from CiteSpace can perceive research communities' attention to specific keywords and publications during different periods. The frequency of the keywords and numbers of citations are first-level indicators representing the research themes. In contrast, keyword burst is a high-level indicator accompanying research attention in a specific period. Therefore, keywords with higher citation bursts can provide critical signals to identify research frontiers. Table 5 shows 12 keywords with higher citation bursts, along with the strength and duration of the bursts from 2000 to 2021 in red. Risk assessment is the first with the most robust citation burst of 4.55, which continued for six years from 2009 to 2015. Urbanization, long-term exposure, and greenspace are the three keywords with higher burst intensity in the past three years, presenting emerging trends and leading frontiers, affecting the development of freshwater blue-health research. Especially, urbanization and long-term exposure have the predominant citation burst of 4.54 and 4.16, respectively.

Urbanization. Urbanization is becoming an inevitable trend worldwide. About half of people live in cities, and it is expected that by 2030, three out of every five people will live in urban areas (Lahariya, 2008). Although living in cities has many advantages, including facilitating social networks and providing many public services, it brings a series of problems that could harm human health, including air and water pollution, noise, stress, etc. (Samet et al., 2000). In recent years, with the deepening of research focus and public attention on health issues, a research focus on the health benefits of blue space has gradually shifted from natural environments (e.g. coastal environment) to the urban context. An increasing volume of evidence has emerged that proximity to urban blue spaces could benefit human health like green space (Burkart et al., 2016; Gascon et al., 2017).

Long-term exposure. Long-term exposure is the necessary supplement for the research on short-term effects. The relationship between long-term exposure and health could be essential for policymakers and designers to take appropriate policy actions or design decisions (Gascon et al., 2015). In many cases, the health benefits of blue space exposure/contact are associated with specific recreational activities (Barton and Pretty, 2010). For instance, improving mental health and social contact were frequently attributed to short-time exposure to blue space. Although the short-term and experimental research could provide evidence for the mechanisms linking blue space and health, they cannot infer causality (Gascon et al., 2015). With more and more studies regarding the freshwater blue space as an essential solution for health issues caused by urbanization (Hartig et al., 2014), it is necessary to examine the health benefits of long-term exposure to freshwater blue space (Chen and Yuan, 2020; Gascon et al., 2018). However, most studies concerning long-term exposure adopted the cross-sectional design, and few used longitudinal data (Gascon et al., 2017). For example, some studies examine the association between the inhabitants' health conditions and the volume and accessibility of blue space (McDougall et al., 2020), assuming that individuals have resided in the study area for an extended period. Gascon et al. (2017) have identified the limitation of ignorance of residential history and pointed out the importance of accurately measuring long-term exposure.

Greenspace. Greenspace and greenness show high strength in burst detection from 2018, indicating their importance in freshwater blue-health research. Green space is a recurring theme in blue-health research, and the relationship between them can be divided into three phases. In the first phase, blue space did not receive much attention. Many studies regard blue space as an element of green space (Völker and Kistemann, 2011), always using terms such as green space (Laumann et al., 2001; van den Berg et al., 2016) and natural environments (Han, 2003) to refer to green and blue space collectively. With the formation of numerous significant research projects and the re-emergence of geography's interest in the water-health relationship, the study of blue space and health transformed into a distinct research topic in the second phase (McDougall et al., 2020). In the third phase, with the development of blue-health research, blue space is defined as 'health-enabling places and spaces, where water is at the center of a range of environments with identifiable potential for promoting human wellbeing' (Foley and Kistemann, 2015). Therefore, the blue space contains the water body and related environments. Green space can be an integral aspect of the surrounding environment of blue space, and recent research indicates that most people in freshwater blue space engage in land-based activities

Table 5
Top 12 keywords with the most robust citation burst.

No	Keywords	Strength	Begin	End	2000-2021
1	Climate	3.6	2007	2013	
2	Risk assessment	4.55	2009	2015	
3	Model	3.56	2009	2013	
4	Environment	3.33	2009	2011	
5	United States	3.62	2010	2017	
6	Neighborhood	3.36	2014	2017	
7	Restoration	3.89	2015	2019	
8	Community	3.66	2015	2016	
9	Greenness	3.31	2018	2019	
10	Urbanization	4.54	2019	2021	
11	Long term exposure	4.16	2019	2021	
12	Greenspace	3.4	2019	2021	

rather than water-based recreation (Elliott et al., 2018; Pasanen et al., 2019). Moreover, recent studies have shown that, in some cases, considering green and blue spaces together can benefit human health more effectively (Haase, 2015).

5. Trending topics in current research

In this section, several trending topics in freshwater blue-health research are identified and then reflected on them from the design perspective. Cluster analysis can provide the thinking basis for identifying trending topics, and this research conducted cluster analysis through VOSviewer and CiteSpace, respectively (Fig. 4). On the other hand, the co-occurrence analysis and co-cited analysis in CiteSpace were used as supplementary material to identify trending topics (Fig. 5 and Fig. 7). Moreover, overlay and density visualizations in VOSviewer could offer solid support for reflection (Fig. 6 and Fig. 9). Based on the synthetic analysis, three trending topics were summarized, including focusing on experience and usage, attaching importance to psychological outcomes, and paying attention to the health benefits of specific age groups.

5.1. Focusing on experience and usage

Although freshwater blue space provides many passive health benefits, including masking traffic noise (Jeon et al., 2010) and managing temperatures in summertime (Völker and Kistemann, 2013), the use of freshwater blue space implies an intentional engagement with water, which is a more direct and critical approach for promoting health (Völker et al., 2018). From the result of the overlay analysis in VOSviewer reflecting the research development over time, freshwater blue-health research before 2015 mainly focused on the physical environment (Fig. 6). Some cyan and purple clusters of keywords demonstrate this trend, including the pathogen, soil, copper, substance, etc. These studies discuss the health promotion role of preventing the harmful effects of freshwater blue spaces, as water has previously been considered breeding grounds for various diseases (WHO, 2002). On the other hand, some researchers regard freshwater blue space as an effective way to optimize the ambient urban environment, positively affecting human health (Shanahan et al., 2015; Völker et al., 2018; You et al., 2010). These two types of studies mainly focus on the intervention in the physical environment of freshwater blue space and are more related to natural science.

With time, the yellow and light green keyword clusters indicate that the focus of freshwater blue-health research has gradually evolved away from natural sciences toward social science (Fig. 6). The research gradually focused on human use and perception of the freshwater blue space, with related keywords including experience, usage, solidarity, place, etc. Although research on human health and freshwater blue space is in its early stages (McDougall et al., 2020), it shares certain similarities with the study on the natural environment, as blue space is a component of the natural ecosystem (van den Berg et al., 2016). Therefore, research on the natural environment and health can be adopted as a meaningful reference for research on freshwater blue space. In nature-health research, the change in people's perceptions of health has led to a considerable transformation (Hartig et al., 2014). With chronic, lifestyle-related health issues being the leading cause of death, the biopsychosocial explanation (Engel, 1977) has gained increasing attention and is viewed as a supplement to the biological paradigm. Alongside the changes in the definition of health, the methods for measuring health outcomes have also expanded, including previous indicators such as morbidity (Maas et al., 2009), morality (Gascon et al., 2017), and longevity (Takano, 2002), and emerging indicators such as self-reported health (Pasanen et al., 2019) and the level of specific cortisol after nature contact (Gidlow et al., 2016). Biopsychosocial research focuses on how people perceive, assess, and use the natural environment. Related studies came from various disciplines, including epidemiology, environmental science, human geography, environmental psychology, urban studies, and landscape architecture (Hartig et al., 2014). Freshwater blue-health research also follows this trend. However, the total volume of research is still limited. In the future, this trend will be reinforced and consistent with other scientific research related to human health, where natural science and social science are always combined when certain stages of development are reached (VanLandingham, 2014).

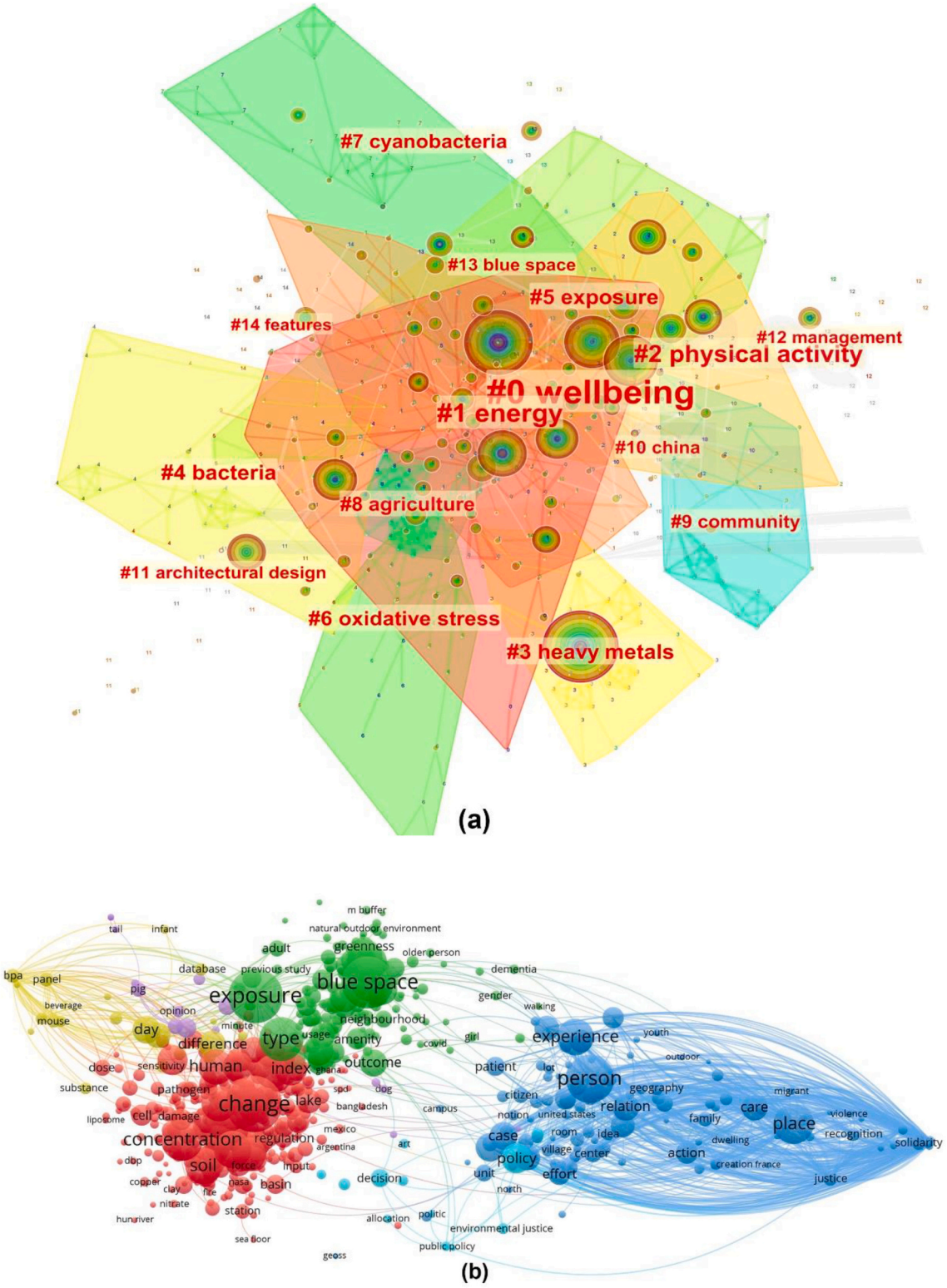

Fig. 4. Keywords-based knowledge clusters from CiteSpace and VOSviewer. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

5.2. Attaching importance to psychological outcomes

The result of the document-based cluster analysis in CiteSpace is illustrated in Fig. 7, which depicts several distinct research clusters based on the co-cited documents network. It is noted that benefits related to psychological outcomes seemed more important than physical activity in the freshwater blue-health research. White et al. (2010) detected that the water was associated with higher perceived restorativeness when people viewed the urban blue scenes than in other environments. Völker et al. (2018) take the two German cities as cases to identify that blue space usage is related to mental health rather than physical health, and Garrett et al. (2019) found similar results from the

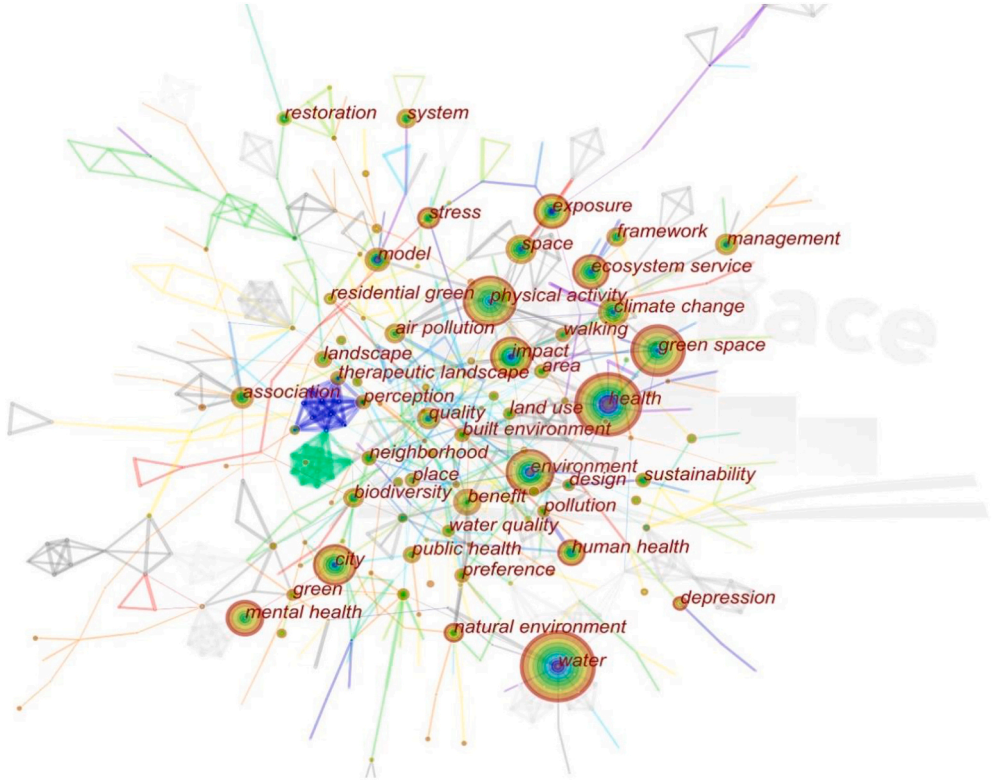

Fig. 5. Knowledge mapping of the keyword co-occurrence network. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

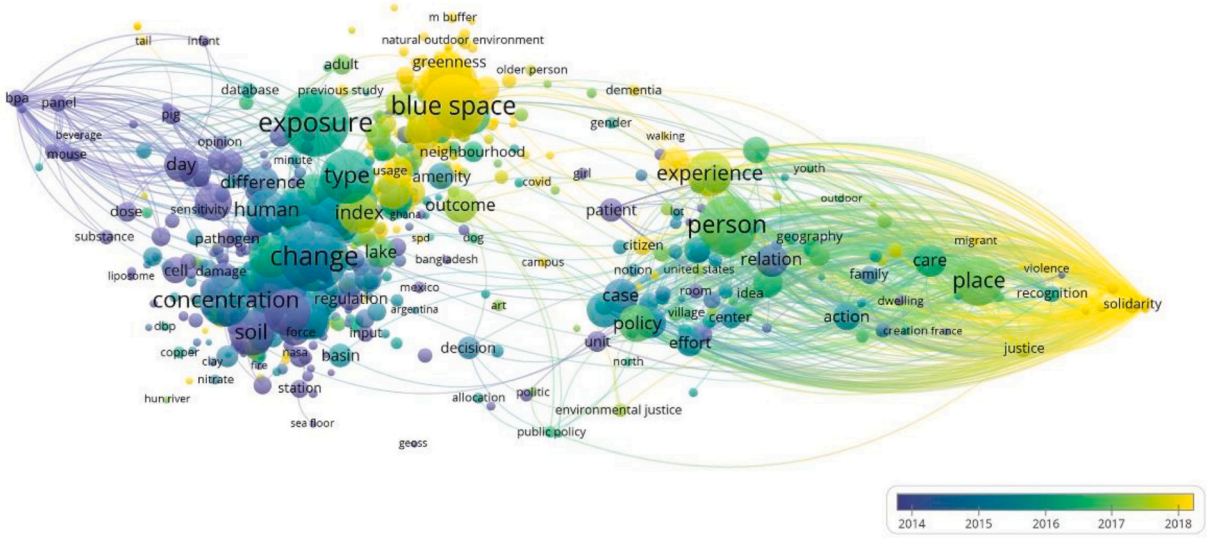

Fig. 6. Keywords overlap map from VOSviewer. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

older adults in Hong Kong. Based on this, the document-based cluster analysis of greenspace was conducted for a comparative study with freshwater blue space. The analysis result of greenspace shows that physical activity plays a more critical role than psychological benefit (Fig. 8). This finding is in line with a Canadian study, which examines the therapeutic impact of green and blue spaces for older adults (aged 65–86 years old) and finds that blue space, in particular, embodies important therapeutic qualities for mental health (Finlay et al., 2015).

This study attempts to explain why research on freshwater blue space focuses more on psychological benefits. First, freshwater blue spaces can enhance mental health by acting as therapeutic or salutogenic spaces with a long history in various cultural contexts. The therapeutic landscape notion is inextricably linked to a psycho-evolutionary theory known as the biophilia hypothesis, which asserts that humans are born with an innate need to interact with nature and other life forms (Dempsey et al., 2018). Historically, blue space was regarded as a place of healing, including spas, baths, and other healing water spaces (Foley and Kistemann, 2015). Gesler's research on healing space described that the health benefits could directly come from water (Gesler, 1992, 1998).

Second, although blue space can provide sufficient space for many

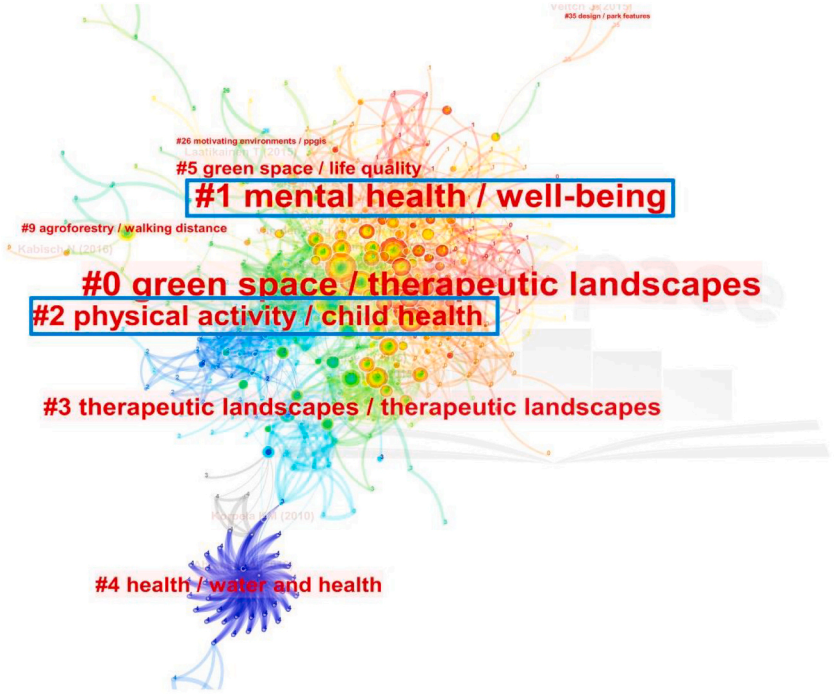

Fig. 7. Co-cited document-based knowledge clusters from freshwater blue space-health research. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

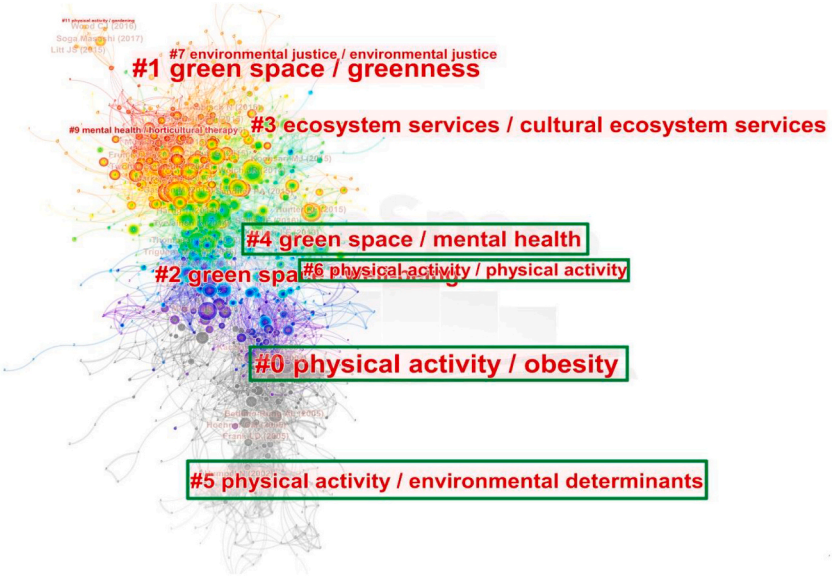

Fig. 8. Co-cited document-based knowledge clusters from green space-health research. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

types of recreation, most people prefer light land-based activities (such as walking, camping, and gathering) to water-based recreations. The health outcomes of these light activities are more related to psychological outcomes. Völker and Kistemann (2013) found that many people just sat near the river and watched its movement, recognizing the flowing water, the waves, the changing colour of the river, and other people's activities. Several studies have identified that blue views can benefit people's mental health, especially for older adults with poor mobility (Coleman and Kearns, 2015; Dempsey et al., 2018; Helbich et al., 2019). Moreover, activities like camping and gathering in blue spaces may be particularly beneficial for positive social relationships, which are also a form of psychological outcomes. Many studies from several cultural contexts suggested that blue space can be ideal for spending time with friends and family (Foley, 2015; Vaeztavakoli et al., 2018; Völker and Kistemann, 2015).

Third, freshwater blue spaces have a great capacity to shield people against poor mental health (White et al., 2020). People are born with a strong need to connect with others or something bigger than themselves (Baumeister and Leary, 1995). Compared to green spaces, freshwater blue spaces like rivers and lakes are more likely to become the symbolic features of cities since green spaces are increasingly and easily encroached upon by construction (Bengston et al., 2004). Freshwater blue space may evoke people's sense of place and help them establish the attachment to a place and place identity. For example, Cologne and

Düsseldorf use the River Rhine as the city's highlight and help to form the place (Völker and Kistemann, 2013). Environmental psychologists have suggested the beneficial and restorative effects of places on well-being (Kearns and Gesler, 1998; Lengen and Kistemann, 2012).

5.3. Paying more attention to the health benefits of specific populations

According to the cluster analysis of CiteSpace and VOSviewer, there are several clusters related to specific populations, including older people, citizens, youth, and children (Fig. 6 and Fig. 7). These clusters show that freshwater blue-health research is gradually shifting toward specific populations. Some studies have identified this situation and called for attention to differences in health benefits among different population subgroups (Frumkin et al., 2017; Hartig et al., 2014; White et al., 2020). Population subgroups have critical differences regarding access, utilization, and response to nature, resulting from spatial, social, economic, ethnic, cultural, and demographic diversities (Hartig et al., 2014). In both studies on green/blue spaces and health, researchers found that the health benefits of contact with green/blue spaces are more significant for poorer than richer individuals (Mitchell et al., 2015; Wheeler et al., 2012). These findings may shed light on the efficacy of green/blue space in alleviating socioeconomic inequities (Hartig et al., 2014). A study conducted in Spain examining the effect of pre/post-intervention on an urban river reveals that the spatial regeneration of rivers may reduce gender and ethnic inequality (Vert et al., 2019a).

Further, some studies reported that men were more likely to visit freshwater urban blue spaces while females were more likely to enjoy coastal settings (Elliott et al., 2018; Vert et al., 2019a). The activities engaged in blue space were also significantly different by gender and age, which further influenced the mechanisms linking exposure and health. For instance, men prefer highly energetic activities and may benefit more from physical activities (White et al., 2020). Older adults with poor mobility may rely more on viewing the blue space to gain mental health benefits (Coleman and Kearns, 2015; Dempsey et al., 2018; Helbich et al., 2019).

Therefore, research on specific populations may provide three strengths. Firstly, it can help avoid population-induced bias and render the results more convincing. Secondly, this kind of research can offer more detailed evidence to help researchers build a more comprehensive understanding of the relationship between freshwater blue space and health. Thirdly, the evidence from different populations could provide a solid basis for designers and policymakers.

5.4. Reflections on the trending topics from the design perspective

These trending topics reflect the demand for more in-depth research into the relationship between freshwater blue space and health while also benefiting design. Specifically, with a greater understanding of how people experience and use freshwater blue space, designers can better arrange space and facilities to improve freshwater blue space's health performance beyond a one-dimensional focus on quantity of provision. In light of the growing emphasis on psychological outcomes, the health benefits of freshwater blue space design projects will be expressed beyond only focusing on increased opportunities for physical activities. Thus, the toolbox for design could expand, as Völker and Kistemann (2013, 2015) notice that many people gain psychological advantages from blue space simply by looking at water and interacting with others while enjoying the blue space. Moreover, the health benefits of exposure to freshwater blue space have often varied by population cohort and their perception of blue space. Understanding the health benefits of specific age groups, especially the elderly and children, can help designers develop a life-course approach. This approach, mentioned by Douglas et al.'s (2017) research on green space, provides opportunities to translate health evidence into design practice.

To conclude, these trending topics may be aligned with public engagement and people-centered goals in design fields (European Commission, 2019). They provide a more robust argument for the health-oriented and evidence-based design approach, as research has demonstrated that design is critical in supporting human health and wellbeing (Sarkar and Webster, 2017).

6. Identifying vacuum in freshwater blue-health research

Despite freshwater blue-health research becoming increasingly in-depth, this study uncovered a substantial research vacuum among current research, lacking practical exploration from the design perspective. From the conceptual framework in section 2, existing studies mainly focused on the upper side relating to the field of public health, including identifying health outcomes, summarizing linking pathways, and collecting research evidence. However, less attention has been paid to research from the bottom side that emphasizes design, including translating health evidence into design concepts, developing practical design knowledge, and applying these concepts and knowledge to real projects. While some studies have proposed methods and recommendations for freshwater blue space design to promote health, this is not always the case. Scientific research findings need to be translated into action (Brownson et al., 2017). Although current research can identify and quantify the health benefits of nature contact, the research related to design interventions still urgently need to determine what works well in practice (Kondo et al., 2015).

The results of the scientometric analysis provide solid evidence to support the discovery of the research vacuum. According to the density map showing the occurrence frequencies of core keywords in VOSviewer, the clusters associated with action are dim, indicating that they have not received enough attention in freshwater blue-health research (Fig. 9). In addition, from the result of the keyword-based network analysis in VOSviewer (Fig. 4b), the light blue keywords can be regarded as the action part for integrating health benefits into practice. Most of them are related to policy formulation or implementation, such as policy, politics, public policy, etc. These keywords imply that most studies seek to achieve the health benefits of freshwater blue space through policy advice, which corresponds to CiteSpace's cluster analysis (Fig. 4a), where the 'management' cluster conveys the same message. However, even though policy measures are mentioned in some articles, they still receive insufficient attention. While many studies conclude with recommendations for policy and design initiatives, the majority of conclusions are broad and lack operability (Chen and Yuan, 2020; Garrett et al., 2019; Vert et al., 2019b; Völker et al., 2018). On the other hand, while actions related to policy and management can contribute to implementing research outcomes, design could be regarded as a direct and practical approach to improving blue space quality (de Bell et al., 2017). Although the cluster 'architectural design' is identified in the keyword-based cluster analysis of CiteSpace (Fig. 4a), the research related to design is still scarce. Further, the keywords associated with 'architectural design' are not frequent, and the cluster is not well-connected with others.

Generally, 'design' can be distinguished into a noun and a verb (Steinitz, 1995). As a noun, design represents the product of the design process in which the design is projected or implemented. From the perspective of viewing design as a noun, several existing studies have explored changes in the health-improving effect of freshwater blue space before and after design and developed some tools for assessing the health benefits of freshwater blue space (Bell et al., 2021; Mishra et al., 2021; van den Bogerd et al., 2021; Vassiljev et al., 2020; Vert et al., 2019b). The BEAT (BlueHealth Environmental Assessment Tool) and BBAT (BlueHealth Behavioral Assessment Tool) are the two representative tools that evaluate the health benefits of blue space and attempt to provide support for the implementation of future projects (Bell et al., 2021; Mishra et al., 2020). These tools are adopted before and after the design is projected or implemented and can be used by multiple stakeholders, including designers, the public, policymakers, and government officials. However, the richness and quantity of such studies are limited

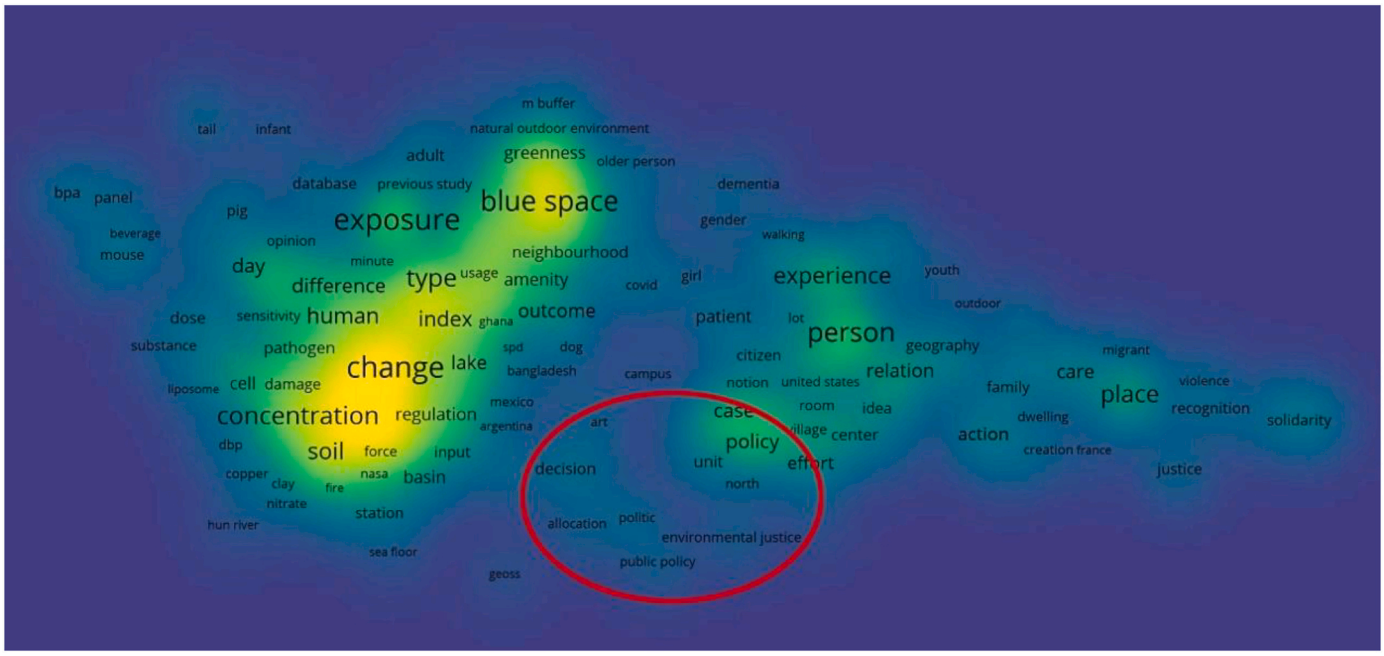

Fig. 9. Keywords density map from VOSviewer. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

in current research.

On the other hand, design as a verb refers to the act of projecting future environments through multi-types of representations, and it is mainly performed by designers (Nijhuis and de Vries, 2019). According to the analysis–synthesis–evaluation (ASE) paradigm, design could be regarded as an integrative practice that allows the interactions among multiple objectives and stakeholders to formulate design decisions (Braha and Maimon, 1997; Jones, 1992). The study of regarding design as a verb mainly focuses on the generation of practical knowledge, which emphasizes the guidance of the design process and provides methodological support for fulfilling the design objectives. However, to our knowledge, almost no studies have explored the practical methodological support for designers to integrate health into freshwater blue space design. Therefore, building a bridge between existing research findings and the design process is necessary. Evidence-based or knowledge-based design approach can be an effective way to close this gap. The framework in section 2 proposes a preliminary and bi-directional methodological support for bridging the health evidence that receives wide attention and practical design knowledge that needs further elaboration in future research.

7. Conclusion

In recent decades, an increasing amount of research activities have been dedicated to exploring the health benefits of freshwater blue spaces to provide an effective approach for establishing healthy cities, which have gained significant prominence in implementing the Sustainable Development Goals (SDGs) and health promotion agendas (WHO, 2020). Therefore, a comprehensive overview of the knowledge regarding the relationship between freshwater blue space, health, and design is needed to understand the current research progress and gap. This study first proposed a six-step bi-directional framework connecting the health evidence with design practice, which can be regarded as a reference for organizing current research and the methodological support for evidence translation. Next, this research studied 1338 publications on freshwater blue-health research with the assistance of scientometric analysis and reflected the results from the design perspective. From 2000 to 2021, the number of publications in this area increased rapidly with broad collaboration among different disciplines. Environmental science, public environmental and occupational health, and environmental studies are dominant fields in this area. The establishment of multi-disciplinary research projects indicates policymakers' growing interests. After the keywords-based analysis, three main research categories are distinguished, including mechanisms linking freshwater blue space and human health, different health benefits of exposure to freshwater blue space, and the relationship with global challenges. Urbanization, long-term exposure, and greenspace with robust citation burst in the past three years indicate the frontiers in freshwater blue-health research. And then, three trending topics in this area were summarized: (1) focusing on experience and usage; (2) attaching importance to psychological outcomes; and (3) paying attention to the health benefits of specific age groups. These trending topics could provide more robust arguments and the basis for the health-oriented and evidence-based design approach. Last, based on the conceptual framework and scientometric analysis results, this research identified the main research vacuum: lacking explorations from the design perspective. This kind of design research could provide a basis for assessing the health impacts of design interventions, as well as practical guidance or knowledge for integrating health benefits into the freshwater blue space design process.

This paper can help researchers comprehensively understand the current research status and find future directions in this area. Moreover, it can facilitate multiple applications of health evidence by practitioners, including the development of HIA or EIA and guidance on the design process. However, this research remains some limitations. First, the data was downloaded from the WoSCC with only English publications, resulting in a linguistic bias and negligence of other databases. Given the studies' nature and authors' preference, some design-related studies may not always be included in WoSCC. Second, although the main research vacuum has been identified, this research does not investigate this vacuum in-depth, only presenting a conceptual framework and some preliminary discussions. Future studies could shed more light on the design perspective to facilitate the practicality and operability of health evidence.

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Haoxiang Zhang: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Steffen Nijhuis:** Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Supervision, Project administration. **Caroline Newton:** Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Supervision, Project administration.

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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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