The Benefits of Urban Blue Spaces for Physical Activity and Mental Health: A Cultural Ecosystem Services Perspective

城市蓝色空间对身体活动与心理健康的益处——基于生态系统文化服务视角

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Abstract

Urban mental health challenges are increasingly prominent, and developing blue spaces that promote physical activities (PA) has become an important approach in urban health planning. However, existing studies are limited by simplified indicators and insufficient understanding of mechanisms, with particularly insufficient attention to the role of PA. From a cultural ecosystem services (CES) perspective, this study proposes an integrated framework linking blue spaces, PA, and mental health, examines the differential roles of PA across distinct research pathways, and introduces a "human-water interaction" (HWI) indicator operationalizing both PA intensity and degree of water contact. Synthesizing current evidence on blue space–mental health research, we identify three priority directions: (1) elucidating the intrinsic mechanisms underlying blue space health benefits; (2) developing HWI-based blue prescriptions; and (3) advancing evidence-based blue space design guided by health outcomes. This review delineates theoretical linkages and frontier advances connecting blue spaces, physical activity, and mental health, offering actionable insights to inform healthy urban planning and design.

摘要：城市居民心理健康问题日益凸显，营造促进身体活动（PA）的蓝色空间已成为城市健康规划的重要途径。然而现有研究尚存在指标简化及机制解析不足的局限，尤其对身体活动的探讨不够充分。本文基于生态系统文化服务（CES）理论，构建了连接蓝色空间、身体活动与心理健康的整合框架，探讨了不同研究路径下身体活动的作用，提出了体现身体活动强度、亲水程度的"人水互动"（HWI）指标。在系统梳理了蓝色空间心理健康研究现状的基础上，本文指出未来三大优先研究方向：阐明蓝色空间健康效益的内在机制、开发基于人水互动的蓝色处方、推进健康效益导向下的蓝色空间循证设计。本文旨在探讨蓝色空间、身体活动与心理健康之间的理论关联与前沿进展，为健康城市的规划设计提供决策参考。

Keywords: Blue spaces; Physical activity; Mental health; Human–water interaction; Evidence-based design

关键词：蓝色空间；身体活动；心理健康；人水互动；循证设计

1.Introduction

Urban areas, as the primary settlements of human populations, have increasingly drawn attention to the relationship between spatial environmental quality and residents' physical and mental health, becoming a central issue in urban planning and public health (Z. Chen, Zhai, Ye, Zhang, & Yu, 2016; Tan, Guo, & Jiang, 2010). Urban residents, particularly those living in megacities, face elevated risks to their mental health (WHO, 2022), making the creation of spatial environments that promote mental health a critical task in urban renewal and the development of livable cities (Du, et al., 2022).

Blue spaces, as part of urban ecological infrastructure, provide multiple ecosystem services to urban residents, including regulatory, cultural, and recreational functions (Yu, 2021). Due to their unique multisensory experiences and restorative effects (Luo, et al., 2023), they serve as key spatial carriers supporting specific physical activities and promoting mental health (White, Elliott, Gascon, Roberts, & Fleming, 2020). Empirical studies have confirmed that exposure to blue spaces can significantly improve residents' mood and reduce the risks of anxiety and depression (M. Georgiou, Morison, Smith, Tieges, & Chastin, 2021). However, existing research still struggles to effectively support fine-grained urban planning of blue spaces aimed at mental health promotion. The main challenges are: first, most studies focus on correlations between macro-level blue space exposure and mental health outcomes (Garrett, Clitherow, White, Wheeler, & Fleming, 2019; Smith, et al., 2021), lacking in-depth analysis of the underlying mechanisms by which specific blue space characteristics influence mental health, thereby limiting actionable evidence for differentiated spatial design; second, blue spaces are often simplified as "visual landscape elements", with many studies neglecting the role of physical space characteristics in facilitating or constraining different types of PA, and the mediating effects and differential health benefits of various activity patterns remain insufficiently explored. Of particular concern, urban blue spaces often undergo channelization or hardening modifications, which significantly impair ecological integrity and the capacity to support PA (Shi, Kondolf, & Li, 2018), limiting the translation of their potential health benefits into actual mental well-being gains for residents.

Against the backdrop of increasingly severe urban mental health challenges, and in response to the core issues of unclear mechanisms and insufficient evidence-based design support for blue space interventions, this paper draws on a cultural ecosystem services perspective to systematically review current research progress and key bottlenecks. We propose an integrated analytical framework linking blue spaces, PA, and mental health, and outline core directions for future research as well as pathways for evidence-based design translation. The primary objectives of this work are threefold: first, to highlight the central role of "human–water interaction" in mediating the health effects of blue spaces and to propose standardized evaluation dimensions; second, to establish a unified theoretical framework that bridges the gap between studies on "spatial exposure–health outcomes" and those on "specific activity–health benefits"; and third, to create a translational pathway from mechanism-focused research to planning practice, providing theoretical support for the design of health-promoting urban blue spaces.

2. Research on Blue Space and Mental Health from a Cultural Ecosystem Services Perspective

Cultural ecosystem services (CES) are used to assess the non-material benefits and psychological well-being that human societies derive from ecosystems (MEA, 2005). As an important component of natural ecosystems, blue spaces provide venues and opportunities for PA, thereby generating health-promoting benefits for both body and mind (Remme, et al., 2021). Residents' exposure to blue spaces and engagement in PA constitute a key process that aligns the provision of these services with human health needs (Zhai, Cheng, Gou, Wang, & Li, 2024). Based on the CES framework, a conceptual pathway linking blue spaces, PA, and mental health can be constructed (Bratman, et al., 2019; Remme, et al., 2021), providing a unified framework to elucidate the underlying logic by which natural environments influence health outcomes through

behavioral mediators.

The Millennium Ecosystem Assessment (MEA) report highlighted the role of CES in promoting human well-being (Corvalan, Hales, & McMichael, 2005), with particularly strong links to the dimensions of "health" and "good social relationships." In the updated international classification of ecosystem services (CICES V5.1), CES is divided into two types: direct and indirect interactions with nature. Within direct interactions, physical engagement with the natural environment is emphasized, and interactions are further categorized as active or passive based on their form (Haines-Young & Potschin, 2018), clarifying the CES categories corresponding to different intensities of PA. In recent years, scholars have increasingly considered recreational exercise as a core indicator for assessing CES (Rodrigues Ferreira Barbosa, et al., 2024; Hao Zhang, Yu, Dong, Zhai, & Shen, 2024), and multiple studies have demonstrated the significant role of outdoor exercise and sports facilities in enhancing CES quality (De Luca, Calcagni, & Tondelli, 2024; Smrekar, Tiran, & Horvat, 2024), gradually establishing a trend of investigating the health benefits of PA within the CES framework (M. Chen, Li, Lin, & Zhou, 2025; Xiao, An, Kuang, & Wu, 2022).

Based on the CES theory, an analytical framework linking blue spaces, PA, and mental health can be constructed, providing a clear logical pathway for related research: 1) analyzing key characteristics of blue spaces that support residents' PA and mental health (corresponding to "structure & function–service–well-being"); 2) examining the effects of PA of varying settings, types, and intensities on the mental health of different population groups (corresponding to "service–well-being"), thereby providing empirical support for "blue prescriptions"; and 3) developing evidence-based design guidelines by integrating mechanistic evidence on how spatial characteristics influence PA and mental health, thereby creating a closed loop that translates basic research into planning and design practice (Figure 1).

3. Existing Research Evidence

3.1 Limitations and Advances in the Evaluation Paradigms of Blue Space Characteristics

Blue space characteristics constitute the material basis for the provision of CES and the generation of mental health benefits, and their assessment directly determines the depth of mechanism analysis and the feasibility of planning applications.

Blue spaces—including all forms of natural and artificial surface water (Smith, et al., 2021)—have received widespread academic attention for their positive effects on residents' health, particularly mental health. Compared with green spaces, blue spaces are considered to have unique or potentially superior value (C. Chen, Hou, Lin, & Ye, 2025; He, 2020). However, research on

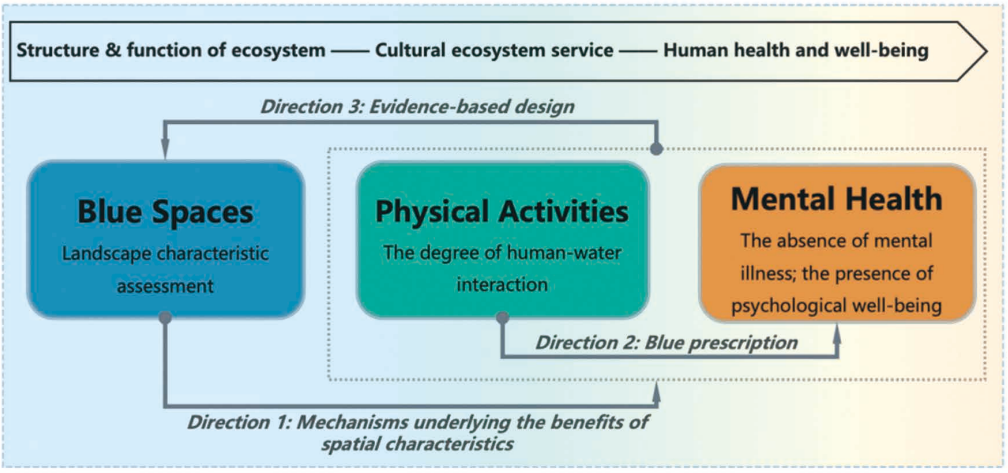

Figure 1. Analytical Framework and Research Directions of "Blue Spaces–Physical Activity–Mental Health"

blue spaces still exhibits significant limitations, including low consistency across studies and insufficient depth in mechanism elucidation (WHO, 2021).

Current mainstream studies rely on macro-level, static exposure indicators in spatial analyses. Most research assesses residents' "exposure" to blue spaces by delineating buffer zones and using geographic indicators such as the presence of water bodies (Keskinen, Rantakokko, Suomi, Rantanen, & Portegijs, 2018), the proportion of water area (Jansen, Kamphuis, Pierik, Ettema, & Dijst, 2018), or proximity (Pasanen, White, Wheeler, Garrett, & Elliott, 2019) (Table 1), and then links these measures to mental health or PA levels. However, this exposure assessment paradigm based on macro indicators has fundamental limitations. The core issue lies in the significant disconnect between artificially defined spatial boundaries (e.g., buffer zones) and the oversimplified assumptions about "exposure" (e.g., considering only distance or area) versus the complex ways in which residents actually perceive and use blue spaces. This results in inaccurate reflections of true exposure levels, poor cross-study comparability, and represents a key bottleneck in the current development of the field.

Recent research has shown two innovative trends, though they have yet to be effectively integrated. On one hand, Landscape Character Assessment (LCA) methods (Bao, Zhou, & Xiao, 2017; Y. Wang & Dong, 2025) and technological innovations—such as the use of social media data and machine learning to identify landscape characteristics—provide new avenues for fine-scale measurement of both perceived and physical characteristics of blue spaces at the local scale (Huang, et al., 2025; W. Li, et al., 2026). On the other hand, a limited number of experimental studies have begun to focus on the direct effects of specific blue space attributes, including space type (Luo, et al., 2023), naturalness (Yin, et al., 2023), and visual openness (Gao, Tao, Kubis, & He, 2023), on mental health.

However, these two research paths remain largely separate. The first (LCA) provides a powerful tool for detailed spatial characterization but has not yet been systematically applied to mechanism studies of blue space and mental health effects. The second (experimental studies) examines the impact of specific spatial characteristics but lacks a systematic framework for evaluating complex, real-world urban landscapes. This disconnect between "characteristics identification" and "health effect validation" prevents research from systematically answering which core blue space characteristics drive health outcomes, and limits the generalizability of experimental findings to real-world urban planning contexts. Systematically integrating fine-scale spatial feature identification with experimental studies on health effects represents a critical breakthrough for advancing the assessment of blue space characteristics and their mental health impacts, and for overcoming current paradigm limitations.

Table 1. Methods for Assessing Blue Space Characteristics in Existing Studies

Measurement Dimension	Operational Definition	Reference
The proportion of blue space	Proportion or density of blue space within predefined residential or activity buffers based on land-cover or water datasets; Water area proportion calculated within spatial units; Visual exposure from street-view imagery	(Duffy, et al., 2024; Jansen, et al., 2018; B. Li, Ouyang, & Liu, 2023; Haoxiang Zhang, Nijhuis, Newton, & Tao, 2024)
The proximity to blue space	Distance to the nearest blue space; Proximity defined using residential buffer thresholds; Network-based accessibility metrics; Self-reported or perceived proximity	(Crooks, et al., 2022; Mohnsam da Silva, et al., 2017; Nicklett, Sharma, & Testa, 2024; Yang, Yang, & Chen, 2024; Zhou, Grady, & Chen, 2017)
The presence of blue space	Objective presence / absence within buffers or administrative units; Self-reported presence of blue spaces in the neighborhood	(Christian, et al., 2017; Keskinen, et al., 2018)
The Spatial Context of Blue Space	Comparison of natural vs. constructed water features; Assessment of blue space alongside other environmental elements	(Bozkurt & Woolley, 2020; Kalinauskas, et al., 2023; Yan, Leng, & Yuan, 2023; J. Zhang, Xiang, Hu, Ma, & Shan, 2023)

3.2 The Role of Physical Activity and the Necessity of Assessing "Human–Water Interactions"

Physical activity represents a primary manifestation of CES provided by blue spaces and serves as a mediating variable linking blue space characteristics to mental health. It is also a key process through which CES is aligned with residents' health needs.

Physical activity (PA), is defined as any bodily movement produced by skeletal muscles that results in energy expenditure, encompassing a wide range of purposes, intensities, and forms (WHO, 2016). Within the framework of blue space health research, PA plays three critical roles:

(1) As a dependent variable, it serves as a quantifiable proxy for health benefits (Gascon, Zijlema, Vert, White, & Nieuwenhuijsen, 2017); PA levels are commonly used to quantify the physical health gains of blue space exposure, together with psychological health and well-being, forming core dimensions of overall health effects (L. Wang & Md Sani, 2024).

(2) As an independent variable, PA in blue space environments is treated as a specific form of exposure, allowing investigation of its unique health effects relative to other environmental contexts (Coventry, et al., 2021; Marini, Mauro, Grigoletto, Toselli, & Maietta Latessa, 2022).

(3) As a mediating variable, PA is considered a central mechanism connecting blue space exposure to health outcomes, elucidating how spatial accessibility and environmental quality promote participation in PA, thereby generating health benefits (Y. Chen & Yuan, 2020; Yang, et al., 2024).

However, these three perspectives have led to considerable inconsistency in the conceptualization and operationalization of PA within the existing literature.

PA conducted in blue spaces demonstrates unique benefits for mental health, with effects varying according to activity type and intensity. Overall, compared to physiological health, the positive impact of blue space PA on mental health has received more consistent empirical support. Waterfront activities have been shown to effectively promote stress recovery and mood improvement (Luo, et al., 2023; Nicolosi, Wilson, Yoshino, & Viren, 2020; Z. Zhang, Mechurova, Resch, Amegbor, & Sabel, 2023), while water-based activities are associated with reductions in depression and anxiety (Rogers, Mallinson, & Peppers, 2014; Wilson, et al., 2023) and, particularly for individuals with mental disorders, exhibit stronger effects on well-being, psychological resilience, and recovery outcomes (Burlingham, Denton, Massey, Vides, & Harper, 2022; van Tulleken, Tipton, Massey, & Harper, 2018).

A key unresolved issue is that participants in waterfront versus water-based activities engage with water in very different ways, yet differences in mental health outcomes and the underlying mechanisms have not been systematically investigated. Preliminary evidence suggests that direct contact with water may confer more comprehensive benefits (Cai, Fang, Zhao, Zhang, & Zhang, 2022), but this finding has not been verified by large-sample empirical studies, and the core pathways driving the differential effects of interaction patterns remain unclear. Current assessment methods for blue space PA remain limited. In recent years, the "human–environment interaction" indicator has been incorporated into studies of green spaces (Z. Li, et al., 2020), and scholars have increasingly recognized that focusing solely on the presence, frequency, or duration of activity fails to capture the quality and manner of interaction between people and water environments during the activity (Leng, Yan, & Yuan, 2022). This limitation represents a key barrier to the systematic elucidation of the underlying mechanisms and transmission pathways by which physical activity in blue spaces drives mental health benefits. Therefore, introducing the indicator of "human–water interaction" (HWI) in blue space health research is both theoretically valuable and practically necessary.

Recreational activities within river corridors can be systematically classified based on the vertical position of the human body relative to the water surface (e.g., instream, banks, riparian upland trail) and the intensity of the activity (Kondolf & Pinto, 2017). The WHO has applied the "degree of water contact" to categorize recreational activities in both coastal and freshwater environments (WHO, 2003). Maximizing multisensory interaction between humans and water is a key principle in blue space landscape design (Bell, 2019), and direct

contact with water has been shown to elicit stronger pleasure and psychological benefits (C. Chen, et al., 2025). This indicates that developing an evaluation system capable of quantifying the multidimensional characteristics of HWI is a central step in linking blue space characteristics, PA behaviors, and health outcomes.

Based on existing research, this study proposes operationalizing the level of HWI along two dimensions: activity intensity (from passive to active) and degree of water contact (from no contact, incidental contact, to whole-body contact). This allows for a standardized classification and labeling of PA in blue spaces according to HWI levels. The core applications of this indicator are threefold: first, it enables quantitative analysis of spatial distribution hotspots and clustering differences of PA across different interaction intensity levels; second, it allows precise identification of blue space characteristics that contribute most to supporting various HWI levels; and third, it facilitates systematic verification of the differential mental health effects associated with different interaction levels, ultimately providing quantifiable evidence for the evidence-based optimization and design of blue spaces.

3.3 Assessment of Mental Health Effects and Current Limitations

Mental health is the key outcome of blue space health promotion, and the precision of its assessment directly determines the accuracy of health benefit evaluation, serving as a central foundation for translating mechanistic research into intervention practice.

The World Health Organization defines mental health as a state in which individuals realize their potential, cope with normal life stress, work productively, and contribute to society, encompassing two core dimensions: the absence of mental illness and the presence of psychological well-being (WHO, 2022). Existing research has confirmed that exposure to blue spaces, mediated by PA, can exert multidimensional positive effects on residents' mental health. These core effects can be categorized into two main types: first, the alleviation of negative emotions, including stress reduction, decreased anxiety, and depressive symptoms, and the mitigation of emotional disorders (Harper, Romeyke, Shergold, Ford, & Danielsen, 2025; Stewart, Nada-Raja, Sanders-Garrick, & Garbett, 2025; Z. Zhang, et al., 2023); and second, the enhancement of positive psychological states, such as improved psychological resilience, cognitive function, and subjective well-being (Boarini, et al., 2024; Franceschi, et al., 2024; Luo, et al., 2023). Additionally, current studies indicate significant population heterogeneity in the mental health benefits of blue space PA, with stronger effects observed among older adults, vulnerable populations, and individuals with chronic illnesses (Michail Georgiou, Tieges, Morison, Smith, & Chastin, 2022; Liu, et al., 2024).

However, the current evaluation systems for the mental health effects of blue space and PA still face two core limitations, which constrain both the depth of mechanism analysis and the practical implementation of interventions. First, the assessment of mental health lacks sufficient granularity. Most existing studies primarily rely on subjective self-report scales, with limited integration of objective physiological indicators such as heart rate variability, electrodermal activity, and cortisol levels. This restricts the comprehensive and objective evaluation of dynamic changes in mental health benefits and reduces the comparability of findings across studies (Zhai, et al., 2024). Second, research on dose–response relationships remains insufficient. Most studies have only established correlations between blue space PA and mental health, without systematically addressing which spatial characteristics, HWI patterns, exposure durations, and frequencies of blue space activities yield optimal mental health outcomes for specific populations. In other words, the precise dosage schemes for "blue prescriptions" (Carreno, et al., 2023) remain underexplored and empirically unverified. This gap represents a key bottleneck preventing the field from moving from correlational analysis to evidence-based intervention design.

4. Future Research Directions

Although current research on the promotion of mental health through urban blue spaces has accumulated substantial empirical evidence, three core constraints remain. At the theoretical level, there is a lack of deep multidisciplinary integration, and the underlying

mechanisms linking blue space physical attributes, PA, and mental health outcomes remain insufficiently explored. At the methodological level, most existing studies rely on static spatial exposure assessments; there is a need to integrate multimodal data and strengthen research on spatial feature analysis and experimental design. At the practical level, evidence-based design remains disconnected from foundational research, and a complete pathway for translating basic research findings into planning and design practice has yet to be established. In response to these unresolved challenges, this study proposes three core future research directions:

Direction 1: Mechanistic Analysis of the Effects of Blue Space Characteristics on PA and Mental Health

Deeply integrate foundational theories regarding ecological spaces, particularly blue spaces, from the disciplines of landscape design, environmental behavior, and public health, and construct a multidimensional blue space evaluation system encompassing basic geographic attributes, landscape characteristics, and perceptual experience.

The core research components include:

(1) Based on the underlying logic of multidisciplinary theoretical integration, conduct landscape characteristics assessment using machine learning models and multi-source data. By combining street-view imagery, social media big data, on-site surveys, and spatial morphology analyses, integrate the spatial classification system from landscape design, scene division standards from environmental behavior, and environmental exposure assessment dimensions from public health to develop a blue space characteristics evaluation method that is scalable across multiple levels and adaptable to interdisciplinary research needs.

(2) Drawing on human–environment interaction theory, the "stimulus–organism–response" (S–O–R) model, and health promotion frameworks, and employing diverse research methods such as behavioral observation, controlled field experiments, and longitudinal studies, systematically analyze the pathways through which different dimensions of blue space characteristics influence HWI behavior patterns, as well as the variations and underlying mechanisms in their effects on mental health outcomes, identifying the core spatial factors and key behavioral mediators driving health benefits.

(3) Focusing on the differentiated needs of adolescents, older adults, and individuals with disabilities, analyze how blue space characteristics differentially promote PA and mental health outcomes across populations, identify core spatial factors for adaptation, and construct a design indicator system for age-friendly and barrier-free blue spaces.

Direction 2: Empirical Research on "Blue Prescriptions" Based on Human–Water Interaction

Taking the Human-Water Interaction (HWI) indicator proposed in this study as the core anchor, this research direction focuses on the mental health effects driven by the full dynamic process of HWI, and conducts comprehensive empirical research on "blue prescriptions" across multiple scenarios and population groups.

The core research components include:

(1) Establish standardized classification and evaluation methods for PA in blue spaces, and, by combining basic statistics and comparative analyses from multiple scenarios and types of waterfront spaces, systematically clarify the differences in mental health outcomes corresponding to different HWI patterns and types of PA.

(2) Employ research methods such as randomized controlled field experiments, long-term longitudinal tracking, and multilevel mediation models to deconstruct the mechanisms of "blue space–physical activity–mental health", clarifying the core causal pathways and mediating roles of HWI in generating health effects.

(3) Conduct differentiated empirical studies of "blue prescriptions" for populations of varying age, gender, and health status, analyze heterogeneity in mental health outcomes, and identify the optimal activity types, intensities, frequencies, and durations for different groups, thereby developing replicable and scalable personalized mental health intervention schemes.

Direction 3: Evidence-Based Design of Urban Blue Spaces for Enhancing Physical Activities and Mental Health

Based on the CES theory, this direction aims to bridge the gap between foundational research and

practical planning, constructing an evidence-based design system for urban blue spaces that promotes both PA and mental health. The core research content includes:

(1) Establishing a full-chain evidence-based design logic: Clarify that evidence-based design relies on insights from the mechanisms of blue space health effects and empirical findings from "blue prescriptions" as the core evidence base. Define how design practices inherit and implement foundational research, ensuring that all strategies are tightly aligned with the goals of enhancing PA and promoting mental health.

(2) Developing health-oriented design guidelines for urban blue spaces at multiple scales: At the regional scale, focus on the protection and restoration of water ecosystems to secure the supply of CES and ensure sustainable health benefits. At the city scale, improve blue space accessibility and equity to expand coverage of health services for all population groups. At the site scale, design HWI scenarios that are PA–friendly and inclusive for all, including vulnerable groups, providing actionable design principles and technical guidance for urban blue space renewal and surface water ecological restoration projects.

(3) Constructing long-term assessment and dynamic monitoring methods for dual-target health benefits: Develop a full-cycle management system covering planning, construction, operation, and benefit evaluation. Continuously track the actual effectiveness of blue spaces in enhancing residents' PA and mental health, enabling iterative optimization and dynamic refinement of evidence-based design strategies.

Based on the core logical chain of "ecosystem structure and function–cultural ecosystem services–human health and well-being", this study constructs a systematic analytical framework of "blue space–physical activity–mental health". The framework aims to establish a comprehensive logical linkage between spatial characteristics, HWI behaviors, and mental health outcomes, providing a unified theoretical basis for interdisciplinary research on blue spaces and mental health. Meanwhile, the two-dimensional evaluation spectrum of HWI proposed in this study precisely clarifies the mediating role and key transmission pathways of HWI, centered on PA, in the association between blue spaces and mental health, further enriching the understanding of the underlying mechanisms of blue space health effects. Building on the full-chain research system established around the analytical framework and three core research directions, this study bridges the gap from spatial characteristics mechanism analysis, causal inference empirical research, to evidence-based design adaptable to diverse populations. It provides theoretical support for health-oriented urban blue space planning and design, the creation of age-friendly and barrier-free environments, and the implementation of "blue prescription" mental health interventions, ultimately promoting deep interdisciplinary integration and synergistic development across landscape planning, urban design, and public health.

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