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A Meta-Analysis of the Impact of Urban Blue Spaces on Residents' Mental Health

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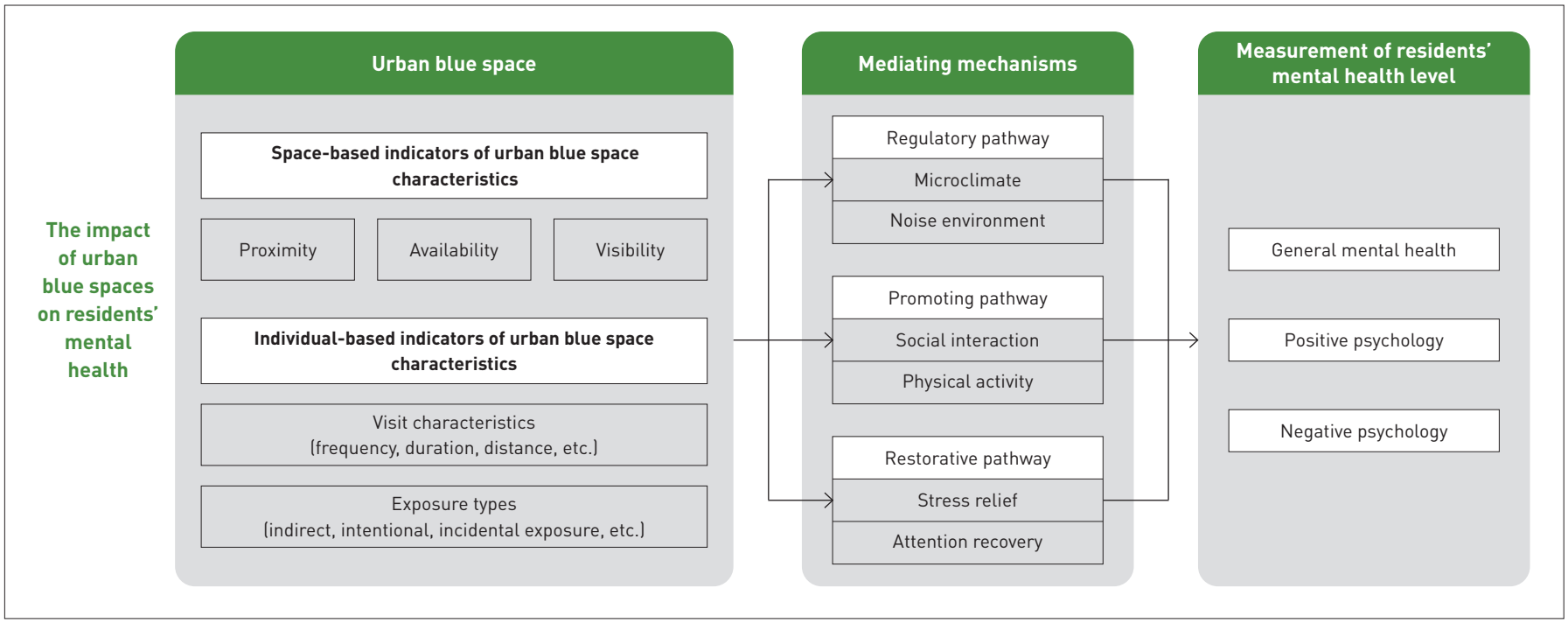
GRAPHICAL ABSTRACT



ABSTRACT

The research on the impact of urban blue spaces on residents' mental health has attracted great attention from scholars internationally, and quantitative studies of the effects dominate the current academia. This study, on the basis of reviewing the theories of urban blue spaces and residents' mental health, conducted a meta-analysis of 47 key studies by systematically selecting and examining the literature from Web of Science, CNKI, and other databases. This paper analyzed the measuring indicators and research models among the literature and standardized the effect size of the research findings. The meta-analysis results include that: 1) the measurements of the characteristics of urban blue spaces are mainly conducted in space-based and individual-based dimensions; 2) residents' mental health is mainly measured from aspects of general mental health, positive psychology, and negative psychology; 3) the proximity of blue space has a significant positive effect in improving residents' general mental health and positive psychology; 4) the availability of blue space is significantly positively correlated with general mental health and positive psychology; 5) although there are studies confirming that factors such as blue space visibility, frequency of visit, and exposure types have an impact on mental health, the relevant studies are still limited; and 6) research on the effect of blue spaces on negative psychology is controversial, especially on mental disorders such as depression, and the findings among existing studies vary significantly. The results of this meta-analysis can provide guidelines for future research and the construction of healthy cities.

KEYWORDS

Urban Blue Spaces; Mental Health; Meta Analysis; Environmental Exposure; Effect Size

HIGHLIGHTS

- Conducts a meta-analysis of the impact of urban blue spaces on residents' mental health
- Clarifies the measuring indicators and research models of the impact of urban blue spaces on residents' mental health
- Quantifies the effect of urban blue spaces on residents' mental health in dimensions of proximity, availability, and visibility
- The effect of urban blue spaces on negative psychology is controversial, especially their effect of depression and other psychological disorders, and the findings among existing studies vary significantly

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1 Introduction

Rapid urbanization, while significantly boosting economic development, has also caused a number of environmental and social issues, posing threats to people's physical and mental health[1]. Statistics indicate that the depression risk rate among Chinese residents reaches as high as 10.6%[2]. Improving public mental health has become one of the United Nations' Sustainable Development Goals[3][4], highlighting mental health as a global concern. Urban blue space refers to all surface water in urban environments[5], including natural water bodies like coasts and lakes, as well as artificial water bodies like fountains and ponds[6]. As a crucial part of the urban natural environment, approximately half of the global population lives within 3 km from blue spaces[7]. These blue spaces not only mitigate the urban heat island effect and promote social activities, but also help alleviate psychological stress, thereby improving mental health[8][9]. Therefore, exploring the influence of urban blue spaces on mental health is of great significance for future urban planning and design.

Scholars have increasingly focused on the relationship between urban blue spaces and mental health, though research results vary. Some studies suggest that residents living near urban blue spaces tend to have better mental health[10], more effective stress recovery[11], and lower rates of antidepressant use[12]. Residents who have regular visits to urban blue spaces report higher subjective well-being[13], while those with more blue space around their residences[14] or more views of blue space[15] report more positive mental health. Compared with urban green spaces, some research indicates that blue spaces have a more pronounced health-promoting effect[16] because they can offer diverse water activities that provide psychological benefits[17]. However, other studies have found no significant correlations between urban blue spaces and mental health indicators due to the variety of geographic environment, research design, and individual factors[18]. Additionally, the effects of urban blue spaces on different types of mental health issues vary[19]; for example, they can reduce anxiety through stress relief pathways but have less effect on depression and other mental disorders[17][20][21]. Given these research disparities, a systematic review of relevant studies is necessary to outline existing theoretical frameworks and discuss research shortcomings and controversies.

Although some reviews have examined the effects of urban blue spaces on mental health, most are qualitative studies and offer limited guidance for future research directions. In contrast, meta-analysis adopts systematic and rigorous literature retrieval and screening criteria, and selects analytical models based on literature heterogeneity to provide more reliable and accurate conclusions[22]. Given the variations in research design and sample size in environmental and health studies, meta-analysis has been increasingly adopted to mitigate individual bias on the overall results[6][23][24]. For instance, Niamh Smith et al. conducted a meta-analysis of 25 studies, revealing the positive effects of blue spaces on residents' obesity rates and mental health[6]; however, this study did not differentiate types of mental health, and the

literature for the meta-analysis was the works published before August 2019. Thus, an updated meta-analysis is needed to more comprehensively and precisely elucidate the effects of urban blue spaces on residents' mental health.

As a response, building on the existing theories of urban blue spaces and mental health, this research screened and analyzed empirical studies published between 2000 and 2022 sourced from databases of WoS (Web of Science), Medline, CNKI (China National Knowledge Infrastructure), and Wanfang Data. The study aims to reveal: 1) the characteristics of urban blue spaces that affect residents' mental health, the types of mental health, and the corresponding measurement methods; and 2) the effect size of each characteristic of urban blue spaces on mental health. This study will provide scientific evidence for urban planning and design practices for improving residents' mental health.

2 Theoretical Foundation and Research Framework

Research on urban blue spaces and mental health, as an emerging branch in the field of environment and health, integrates theory and knowledge systems from disciplines such as health geography, landscape ecology, and environmental psychology. Despite the varied interests of different disciplines, they collectively provide theoretical support for understanding the influencing mechanisms of urban blue spaces on residents' mental health[8].

Specifically, research in health geography is centered on the Social-ecological Theory, regarding urban blue spaces as crucial components of the built environment that can influence residents' mental health directly or indirectly[25][26]. Such studies often operate on a macro scale (e.g., national, regional, city), using large-scale standardized survey data (with analytical unit of community), and explore the heterogeneity of urban blue spaces' effects on mental health across different community types.

Landscape ecology research, supported by the Ecosystem Services Theory, examines the relationship between urban blue spaces and residents' mental health from a supply-demand perspective, proposing evaluation models for the health benefits of natural environments[27]. This theory considers urban blue spaces as an essential component of urban ecosystems, where blue spaces are the supplier of ecosystem services and residents are the demander. The effective matching of supplier and demander occurs through environmental exposure and contact[28], where residents engage with urban blue spaces via multi-sensory perception (e.g., visual, auditory) to promote mental health. Such studies typically focus on meso- and micro-scales (e.g., community, single or several sites of blue spaces), emphasizing the differential impacts of various types of urban blue spaces on mental health.

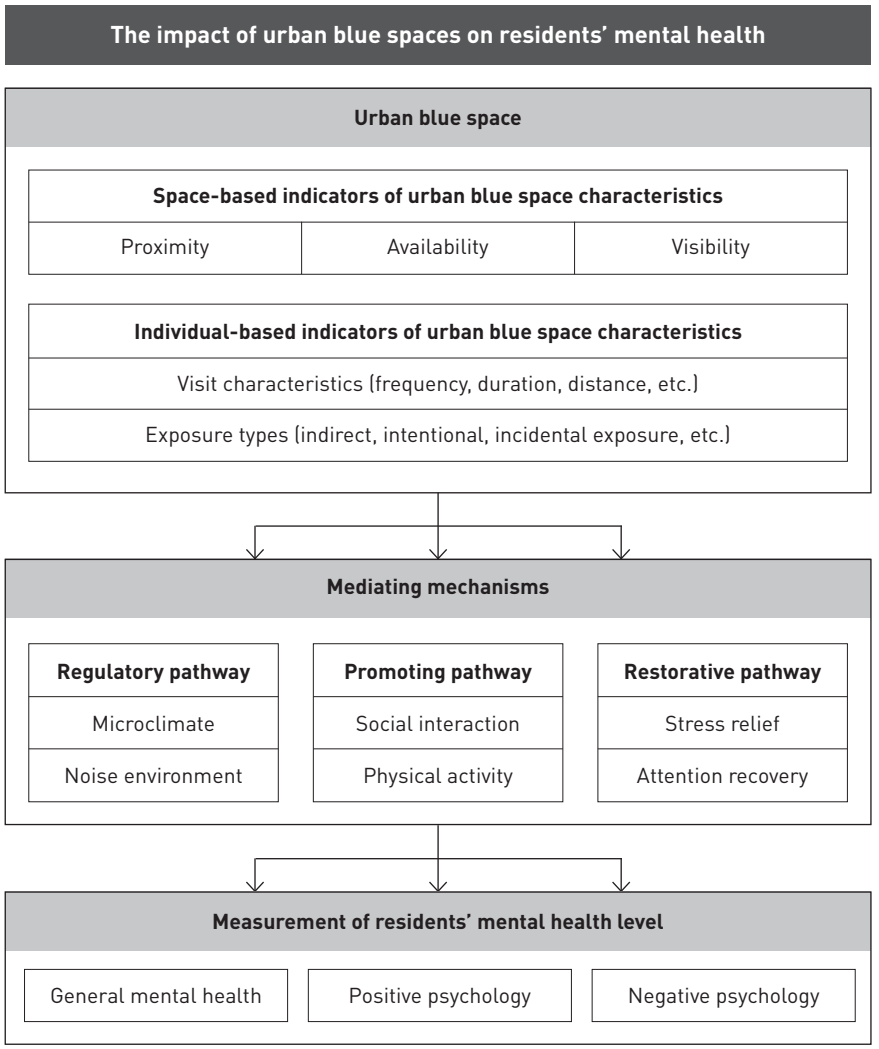
In environmental psychology, the Attention Restoration Theory and the Biophilia Hypothesis are the most widely discussed foundational theories. The former, proposed by American environmental psychologists Stephen and Rachel Kaplan, posits that natural environmental elements (including blue spaces) have eight restorative qualities—such as being away, extent, and mystery—that aid in the recovery of directed attention[29][30]. And the latter, emphasizing humans' innate affinity for nature, holds that nature plays a significant role in healing and improving human mental and physical health[31]. Similar to that in landscape ecology, environmental psychology research also focuses on meso- and micro-scales and utilizes experimental methods to explore the differential impacts of urban blue space characteristics and exposure types on residents' mental health.

Despite the disparity of research emphases across disciplines, all of them stress the significant role of urban blue spaces in strengthening residents' mental well-being, by measuring spatial dimensions (e.g., proximity, availability, visibility) and individual dimensions (e.g., visiting characteristics, exposure types). The influence of urban blue spaces on mental health can be summarized into three pathways[8][32]. 1) Regulatory pathway: urban blue spaces regulate microclimates (e.g., reducing temperature, increasing humidity), improving residents' psychological and emotional states[33]; additionally, sounds from water bodies like streams and fountains can improve the soundscape, enhancing psychological comfort[34]. 2) Promoting pathway: urban blue spaces can provide places for physical and recreational activities that promote mental health[17][35]~[37], and also foster social interactions, enhancing a sense of belonging and neighborhood cohesion, which benefits mental health[38]. 3) Restorative pathway: as a vital component of natural environments, urban blue spaces can relieve psychological stress and restore attention, thereby promoting mental health[8] (Fig. 1).

3 Data and Methods

3.1 Data Sources

Sourcing from databases of CNKI and Wanfang Data for Chinese literature, and WoS and Medline for English literature, this meta-analysis constructed three thematic keyword inventories, "blue space," "resident," and "mental health" in both languages (Table 1). Literature searches were conducted using these combined keywords, covering the works published from January 1, 2000, to December 31, 2022, among relevant fields such as "Urban Studies," "Geography,"



1. Theoretical framework of the impact of urban blue spaces on residents' mental health.
2. Literature searching and screening procedure.

Table 1: Literature retrieval subject terms used in this study

Category	Language	Subject terms
Blue space	Chinese	蓝色空间；江；河；湖；海；滨水；海岸；河岸；湿地
	English	Blue space; river; lake; sea; ocean; waterfront; coastal; coast; riparian; wetland
Resident	Chinese	居民；人；公众；老人；儿童；青少年；学生
	English	Resident; people; public; old; children; teenager; student
Mental health	Chinese	心理健康；抑郁；焦虑；幸福；情绪；压力；强迫症
	English	Mental health; depression; anxiety; well-being; emotion; stress; obsessive-compulsive

and "Environmental Sciences." Additionally, a further search was performed among the "highly cited papers" from WoS. In total, 5,765 journal articles were collected (Fig. 2).

Subsequently, a two-step screening process was employed to select the valid samples. The initial screening, using the Rayyan (a tool for systematic literature review) examined titles, abstracts, and keywords to remove duplicates and irrelevant studies, and obtained 481 articles (432 in English and 49 in Chinese). The second round screening was to select empirical studies through full-text reading: 1) selecting empirical studies that employed cross-section analysis, longitudinal analysis, randomized crossover trial or group experiment, and excluding qualitative studies; 2) selecting natural and constructed blue spaces in urban areas, and excluding studies which utilized blue spaces as an intermediary factor or mixed with green spaces; 3) selecting research that focused on urban regions, and excluding those studied microelements and microorganisms; 4) eliminating the literature without available full text. This process yielded 47 eligible articles[10]~[15][17][18][20][21][32]~[36][38]~[69], 45 in English and 2 in Chinese (Table 2).

3.2 Research Methods

Meta-analysis typically includes both qualitative summarization and quantitative synthesis[6]. Qualitative summarization provides an overview of the included studies, encompassing research design, measurement indicators, sample characteristics, etc. Quantitative synthesis is conducted by combining effect sizes, such as standardized mean difference (*SMD*) and correlation coefficients, to represent the strength of the correlation between two variables.

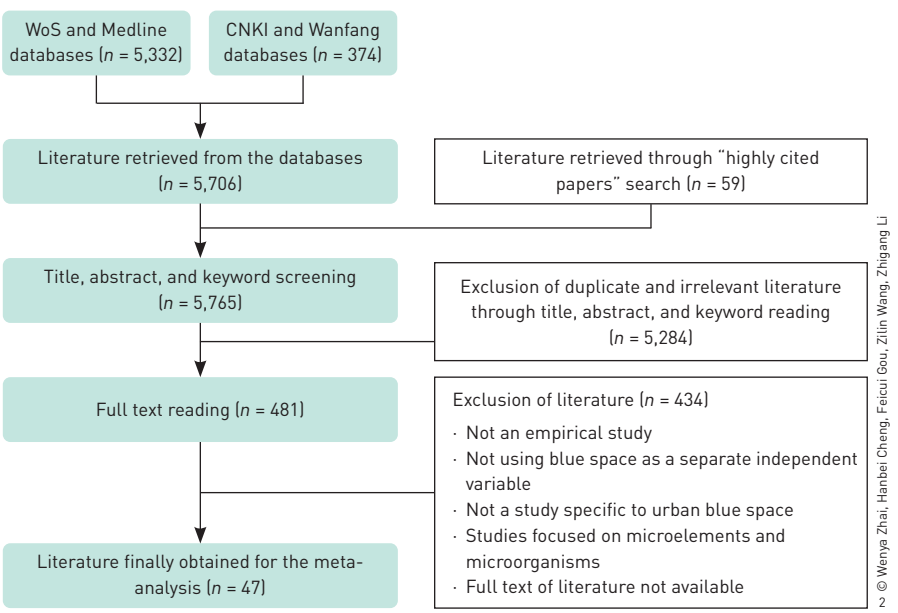


Table 2: List of selected literature for meta-analysis in the research

Literature No.	Published year	Country/region of case study	Population	Indicator(s) of characteristics of urban blue space	Indicator(s) of types of residents' mental health	Research model
39	2010	Finland	Adults	Favorite blue space type; visit frequency; visit duration	Restorative experience	Cross-section analysis
18	2013	England	Adults	Euclidean distance to blue space from residence	Self-reported mental health; life satisfaction	Longitudinal analysis
40	2013	Canada	Children (students)	Presence of blue space within a 5-km buffer from school	Subjective well-being	Cross-section analysis
41	2013	England	Adults	Visit duration; distance travelled	Self-reported emotional restoration	Cross-section analysis
42	2014	Spain	Children (students)	Visits per year	ADHD/inattention	Cross-section analysis
43	2014	USA	Adults (veterans)	Weekly surfing for 5 consecutive weeks	Post Traumatic Stress Disorder (PTSD) and depression	Controlled experiment
36	2015	Spain	Adults	Presence of blue space within a 300-m buffer from residence	Self-reported mental health; depression and/or anxiety; visits to mental health specialists; intake of medication	Cross-section analysis
44	2015	Scotland	Adults (employees of science park workplaces)	Window view of blue space from usual work-station	Subjective well-being	Cross-section analysis
45	2016	The Netherlands	Adults	Percentage of blue space within a 1-km buffer from residence	Mental disorder; self-reported mental health	Cross-section analysis
46	2016	New Zealand	Adults	Blue space visibility of each cell in a residential grid	Stress	Cross-section analysis
13	2017	England	Adults	Neighborhood exposure; visit frequency; whether visiting blue space yesterday	Subjective well-being	Cross-section analysis
33	2017	Spain	Adults (individuals with psychological distress)	Physical activities and social interactions in blue spaces	Self-reported mental health, and physiological measures (blood pressure, heart rate, salivary cortisol, etc.)	Randomized crossover trial
17	2018	Spain	Adults (Alzheimer and families)	Presence of blue space within 100-m, 300-m, and 550-m buffers from residence	Depression; anxiety	Cross-section analysis
21	2018	The Netherlands	All-aged (psychiatric patients)	Percentage of blue space within a 300-m buffer	Duration of hospital admission	Cross-section analysis

(Continued)

Table 2: List of selected literature for meta-analysis in the research (Continued)

Literature No.	Published year	Country/region of case study	Population	Indicator(s) of characteristics of urban blue space	Indicator(s) of types of residents' mental health	Research model
47	2018	USA	Children	Euclidean distance to blue space; presence of blue space within 250- and 1,250-m buffers from residence	Odds of high depression	Cross-section analysis
48	2018	Ireland	Older adults	Euclidean distance to blue space; share of visible blue space from residence	Depression	Cross-section analysis
49	2018	Bulgaria	Younger adults (students)	Euclidean distance to blue space; presence of blue space within a 300-m buffer	Self-reported mental health	Cross-section analysis
50	2018	Bulgaria	Younger adults (students)	Presence of blue space within 100-m, 300-m, and 550-m buffers from residence	Self-reported mental health	Longitudinal analysis
51	2018	Germany	Adults	Visit frequency; perceived walking distance to blue space	Self-reported mental health	Cross-section analysis
52	2018	Switzerland	Adults	Field trip	Physiological parameters; stress; attention restoration	Controlled experiment
10	2019	England	Adults	Euclidean distance to blue space	Self-reported mental health; anxiety and depression	Cross-section analysis
32	2019	Hong Kong, China	Older adults	Blue space quality (rating on safety, presence of wildlife, whether generally be free from litter, and have good facilities); types of exposures; visit frequency; walking distance to blue space; activity intensity; visit duration	Subjective well-being	Cross-section analysis
35	2019	England	Adults	Euclidean distance to blue space; freshwater presence	Self-reported mental health	Cross-section analysis
53	2019	New Zealand	Children (students)	Euclidean distance to blue space; presence of inland blue space in the neighborhood	Subjective well-being; depression	Cross-section analysis
54	2019	Chinese mainland	Older adults	Ratio of the number of blue space pixels per street view image; Normalized Difference Water Index (NDWI)	Geriatric depression	Cross-section analysis
55	2019	Singapore	Children (students)	Whether visit blue spaces	Momentary happiness	Cross-section analysis
56	2019	UK	Adults	Taking part in twice a week wetland nature-based health intervention for six weeks	Subjective well-being; stress; anxiety	Controlled experiment
11	2020	Spain	Adults	Walking distance to blue space from residence; visit frequency; visit duration	Perceived restorativeness	Cross-section analysis

(Continued)

Table 2: List of selected literature for meta-analysis in the research (Continued)

Literature No.	Published year	Country/region of case study	Population	Indicator(s) of characteristics of urban blue space	Indicator(s) of types of residents' mental health	Research model
15	2020	Chinese mainland	Adults	Ratio of the number of blue space pixels per street view image; blue space within a 1,500-m buffer from residence	Self-reported mental health	Cross-section analysis
57	2020	Chinese mainland	Older adults	Euclidean distance to blue space; NDWI	Self-reported mental health	Cross-section analysis
58	2020	Chinese mainland	Older adults	Euclidean distance to blue space; ratio of blue space, per capita water area, and patch separation index of blue space within a 1-km buffer	Self-reported mental health	Cross-section analysis
59	2020	Spain	Adults	Walking in blue space (on 4 days each week, 20 min per day, for 3 weeks)	Subjective well-being; self-reported mental health; mood disturbance; physiological parameters	Randomized crossover trial
12	2021	Scotland	Older adults	Euclidean distance to blue space; percentage of blue space within 800-m and 1,600-m buffers from residence	Antidepressant medication prevalence	Cross-section analysis
14	2021	Chinese mainland	Adults	Percentage of blue space within a 500-m buffer from residence and a 200-m buffer around travel route	Subjective well-being	Cross-section analysis
20	2021	The Netherlands	Adults	Proportion of blue space within 50-m and 100-m buffers from residence	Depression	Cross-section analysis
34	2021	USA	Younger adults (students)	Walking in blue spaces (compared with walking in the urban environment)	Restorative experience	Randomized crossover trial
38	2021	UK	Adults	Visit frequency	Subjective well-being; life satisfaction	Cross-section analysis
60	2021	Chinese mainland	All-aged	Euclidian distance to blue space; blue space area within 300-m, 500-m, and 1,000-m buffers from residence	Depression; subjective well-being	Cross-section analysis
61	2021	18 countries/ regions including the UK and the USA	Adults	Percentage of blue space within a 1,000-m buffer from residence; visit frequency in the last 4 weeks; nature connectedness	Subjective well-being; mental distress; depression/anxiety medication use	Cross-section analysis
62	2021	Denmark	Adults (blood donors)	Percentage of blue space within 500-m, 1,000-m, and 3,000-m buffers from residence	Subjective well-being	Longitudinal analysis
63	2021	Belgium	Adults	Whether live in coastal cities; visit frequency	Subjective well-being	Cross-section analysis

(Continued)

Table 2: List of selected literature for meta-analysis in the research (Continued)

Literature No.	Published year	Country/region of case study	Population	Indicator(s) of characteristics of urban blue space	Indicator(s) of types of residents' mental health	Research model
64	2021	Chinese mainland	Children	Environmental characteristics of blue space based on the adolescents' activity paths in the park	Restorative perception	Cross-section analysis
65	2022	18 countries/ regions including the UK and USA	Adults	Childhood exposure to blue spaces (availability, parents/guardians' attitude to blue space visits, and visit frequency); visit frequency in adulthood	Subjective well-being	Cross-section analysis
66	2022	USA	Adults	Visit frequency; distance to blue space from residence; visit duration	Stress; subjective well-being; life satisfaction	Cross-section analysis
67	2022	England; Welsh	Adults	Whether can see blue space; whether visit blue space in the past 24 hours	Self-reported mental health	Cross-section analysis
68	2022	UK	Adults	Perceived proximity to blue space from residence; visit frequency; contact time	Subjective well-being	Cross-section analysis
69	2022	Belgium	Younger adults (students)	Rating for blue space pictures	Restorative perception	Cross-section analysis

NOTE

Due to the disparity of the classification of research population' among different countries/regions and studies, the statistics in this study were conducted according to the sample characteristics in included literature as 1) children: 0 ~ 18 years old; 2) younger adults: 18 ~ 35 years old; 3) adults: 18 years old and above; 4) older adults: mainly 50 years old and above; and 5) all-aged: covering multiple age groups.

Among environmental health meta-analyses, *SMD* is often adopted as the indicator of effect size[23][24]. In this paper, health effect size refers to the variables' impact on health, and the quantitative synthesis comprises two steps: 1) using Psychometrica, an effect size conversion calculator, the effect sizes of some included studies were converted to *SMD*; 2) using RevMan 5.4 software, the sample sizes and converted *SMD* values were aggregated—due to the heterogeneity of psychological health dimensions among study subjects, indicated by a high I^2 (I-squared, a statistical measure for heterogeneity in meta-analysis), a random effect model was used[23][70]. Given the disparity of research design and the feasibility of effect size conversion, not all included studies were suitable for quantitative synthesis. Therefore, only the studies meeting the requirements underwent effect size aggregation, while the others were performed qualitative summarization.

4 Results Analysis

Statistical results (Fig. 3) indicate that the number of publications has shown a fluctuating upward trend since 2010, with a peak period from 2018 to 2022, during which 74.5% of the total literature was published. Totally, 29 articles took adults as research subject, followed by 6 studies focusing on children and older adults each, 4 on younger adults, and 2 on all-aged groups. Geographically, 29 studies were conducted in Europe, 9 in Asia, 5 in North America, 2 in Oceania, and 2 were cross-continental.

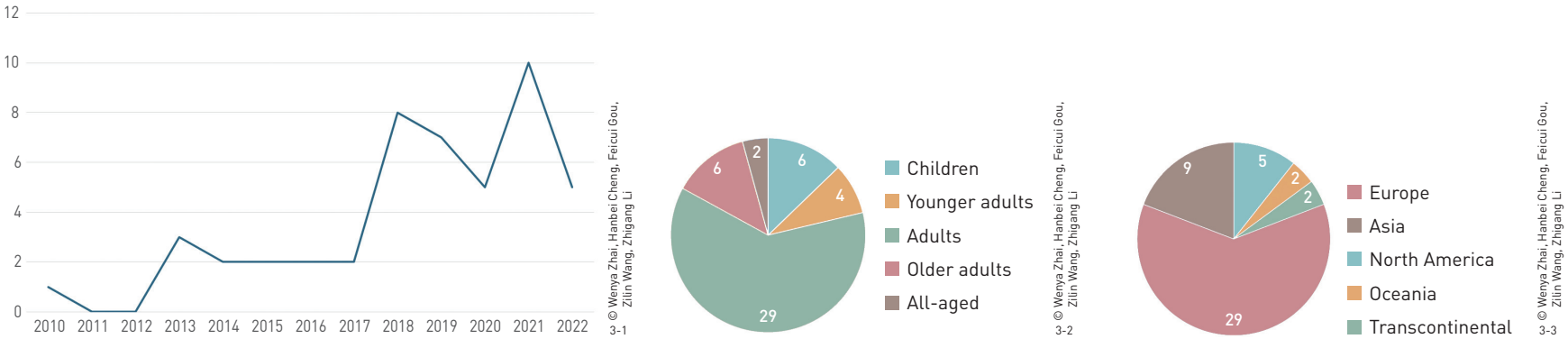
4.1 Measurement and Models of Urban Blue Space Characteristics and Residents' Mental Health

4.1.1 Measurement of Urban Blue Space Characteristics

Among the included literature, the measurement of the characteristics of urban blue spaces was conducted from the space-based (i.e., residential or workplace) dimension or individual-based (i.e., respondent) dimension. The number of space-based and individual-based is 21 for each, while 5 studies combining the both.

(1) Measurement from space-based dimension

Space-based measurements typically use macro data (e.g., land use and transportation data) to determine residents' exposure levels to urban blue spaces. Such studies generally assume



3. Statistics of the included literature for meta-analysis (3-1. published year; 3-2. research subjects; 3-3. geographical distribution).

residents remain stationary throughout the day, and use the blue spaces within the buffers around their residence or workplace (often in a radius of 0.3 ~ 1.5 km) to represent the exposure level, indicated by proximity, availability, and visibility. Proximity refers to whether live in coastal areas[63], the Euclidean distance from the population centroid of the analysis unit to the urban blue space[10][12][13][18][35][47][48][49][53][57][58][60]; availability is determined by the presence of urban blue spaces within the given buffers[17][36][40][47][49][50], percentage of blue space in area[12][14][15][20][21][45][58][60]~[62] or per capita blue space area[58]; and visibility is usually measured by the visible rate of urban blue spaces from specific locations based on land use and elevation data[46][48]. With advancements in artificial intelligence and big data, some researchers have started using street view images and deep learning techniques to measure the proportion of urban blue spaces within certain visible ranges[15][54].

However, statically measuring residents' exposure to urban blue spaces sees limitations. The Uncertain Geographic Context Problem (UGCoP)[71][72] indicates that results would vary depending on the different divisions of geographic units (e.g., community, census tract, postal code precinct)[73]. Additionally, the Neighborhood Effect Averaging Problem (NEAP)[74] highlights that static measurement methods cannot capture variations of individual visit characteristics, economic status, and exposure types, leading to discrepancies between measured and actual exposure levels.

(2) Measurement from individual-based dimension

Individual-based measurements often use survey data to assess residents' active visit to urban blue spaces, and can accurately evaluate exposure levels by examining individual behavioral characteristics and exposure types to urban blue spaces. The former focuses on the influence of individual behavioral characteristics including whether urban blue space is visible[44], whether residents visit[13][41][55][67], frequency/number of visits[11][13][32][38][39][42][51][61][63][65][66][68], travel distance[11][32][51][66][68], duration of visit[11][32][39][66][68], and residents' activity types taken place within blue spaces[33][34][43][52][56][59][64] on mental health. The latter explores the different impacts of different exposure types including indirect exposure (visible from home), incidental exposure (visible during commute), intentional exposure (purposeful visit)[32], and virtual exposure (viewing photos of blue space[69]) on mental health.

(3) Measurement combined space- and individual-based dimensions

The studies considering both space- and individual-based dimensions tracked urban residents' spatio-temporal behaviors through activity logs, calculate blue space coverage around homes and travel routes[14][20], or survey residents' addresses and urban blue space visitation data to comprehensively assess individual exposure levels to urban blue spaces[13][61][63].

4.1.2 Measurement of Residents' Mental Health

In the selected literature, the measurement of residents' mental health mainly focuses on three aspects: general mental health, positive psychology, and negative psychology (Table 3). General mental health is often assessed using overall questionnaires to evaluate individuals' psychological status. Positive psychology involves self-reported well-being (including subjective happiness and life satisfaction), perceived restorativeness, and positive emotions; negative psychology includes negative emotions (e.g., stress, frustration), and mental disorders (e.g., generalized anxiety disorder, depression). Additionally, a few studies examine mental

health with medical statistics (e.g., duration of hospital admission, incidence of depression disorder) and physiological indicators (e.g., blood pressure, heart rate).

4.1.3 Research Models

The research models in the selected literature mainly include observational studies and experimental studies. Observational studies generally use cross-section or longitudinal analyses to explore the effect of urban blue space characteristics on residents' mental health through models such as multiple linear regression[11], Poisso regression[48], structural equation modelling[49], and mediation effect model[57], and analyze their spatial heterogeneity. Cross-section analysis is easier to obtain data and more used to explore correlations, while longitudinal analysis is often used for in-depth investigation of influencing mechanisms, though more challenging in data collection.

Experimental studies typically employ randomized crossover trials[33][34][59] or controlled experiments[43][52][56] that require respondents to be exposed to urban blue spaces in virtual (e.g., viewing photos[69]) or real experiences (e.g., surfing[43], walking[34]) to observe the mental health effects obtained. These studies can better control experimental conditions such as exposure duration and mode, resulting in a more accurate assessment of short-term effects of blue space on mental health. However, due to the difficulty of recruiting respondents, the results of such studies may be biased by the limited sample size.

Table 3: Overview of methods for measuring the level of mental health

Mental health		Measurement method	Literature
General mental health		The General Health Questionnaire (GHQ-12)	Refs. [10][15][18][33][35][36][50]
		Mental Health Inventory (MHI-5, a sub-scale 36-Item Short Form Survey)	Refs. [45][57]~[60][66]
		12-Item Short Form Health Survey (SF-12)	Refs. [51][62]
		Spanish short version of the Profile of Mood States (POMS)	Refs. [33][59]
		10 questions about current emotions using a 5-point Likert scale	Ref. [67]
Positive psychology	Self-reported well-being	The World Health Organization's Five Wellbeing Indexes (WHO-5)	Refs. [14][32][38][53][59][61][65][68]
		The Short Warwick Edinburgh Mental Well-being Scale (SWEMWBS)/Warwick-Edinburgh Mental Well-being Scale (WEMWBS)	Refs. [44][56][63]
		Four subjective well-being questions (life satisfaction) developed by the UK's Office of National Statistics	Refs. [13][59][60]
		A single question assessing overall life satisfaction	Refs. [18][66]
		Cantril Ladder	Ref. [40]
	Perceived Restorativeness	Perceived Restorativeness Scale (PRS)	Refs. [11][64][69]
		Restoration Outcome Scales (ROS)	Refs. [11][39]
		Short-version revised restoration scale (SRRS)	Ref. [34]
		Emotional restoration survey overview	Ref. [41]
	Positive emotions	Positive and Negative Affect Schedule PANAS (positive)	Ref. [56]
	Others	Reporting "happy moments" at any point in time by pressing one of the sensor buttons	Ref. [55]

(Continued)

Table 3: Overview of methods for measuring the level of mental health (Continued)

Mental health		Measurement method	Literature
Negative psychology	Negative emotions	Perceived Stress Scale (PSS)	Refs. [56][66]
		Kessler Psychological Distress Scale (K10)	Ref. [46]
		Positive and Negative Affect Schedule PANAS (negative)	Ref. [56]
	Mental disorder	The anxious/depression dimension of the EuroQOL five dimensions questionnaire (EQ-5D)	Ref. [10]
		Patient Health Questionnaire (PHQ-9)	Ref. [20]
		ADHD/DSM-IV questionnaires	Ref. [42]
		The Major Depression Inventory (MDI)	Ref. [43]
		The Post Traumatic Stress Disorder Checklist Military Version (PCL-M)	Ref. [43]
		McKnight Risk Factor Survey (MRFS)	Ref. [47]
		The Center for Epidemiologic Studies Depression Scale (CES-D)	Ref. [48]
		Short form of the Reynolds Adolescent Depression Scale (RADS-SF)	Ref. [53]
		The shortened Geriatric Depression Scale (GDS-15)	Ref. [54]
		Generalized Anxiety Disorder Scale (GAD-7)	Ref. [56]
	Others	Self-reported visits to mental health specialists; history of anxiety or depression; history of medication; frequency of medication intake	Refs. [12][17][36][61]
		Observation of different physiological effects on blood pressure or heart rates	Refs. [52][59]
		The duration of hospital admission for patients of mental disorders	Ref. [21]

4.2 Effect of Urban Blue Space Characteristics on Residents' Mental Health

4.2.1 Effect of Urban Blue Space Characteristics on Residents' Mental Health Through Space-based Measurement

In this meta-analysis, space-based studies measured the correlations between urban blue space characteristics and residents' mental health from aspects of proximity, availability, and visibility.

(1) Proximity

Meta-analysis results (Table 4) indicate that the proximity of urban blue spaces is significantly positively correlated with residents' self-reported general mental health (*SMD* = 0.33, $p = 0.0001$) and positive psychology (*SMD* = 0.15, $p = 0.006$). Specifically, residents living near urban blue spaces (e.g., those close to coasts or rivers) generally have better self-reported mental health[57], which is particularly significant among low-income groups[10] and strengthens with longer residency[18]. Studies also found that outdoor activities (e.g., walking in coastal area) and perceived restorative quality of the living environment[49] are the affecting pathways of urban blue spaces on mental health. For example, a study in Belgium found that coastal residents experienced higher happiness during pandemic lockdowns than inland residents[63].

However, studies on the effect of proximity to urban blue spaces on negative emotions show inconsistent results. Meta-analysis results suggest that the proximity to urban blue spaces does not significantly influence negative emotions (*SMD* = –0.33, $p = 0.10$), especially for children[40][53]. This may be due to the complex and diverse factors influencing negative emotions, where blue space

exposure, though helpful in alleviating anxiety and stress, may play a limited role, especially in treating mental disorders like depression. Additionally, different age groups may have varying attitudes and usage patterns of urban blue spaces, with adults possibly requiring more emotional solace and psychological recovery from natural landscapes, enhancing the positive effects of urban blue spaces on their mental health[40]. Lastly, geographical variety can also impact exposure effects. For example, a study in the UK proved the positive effects of proximity to the coast on residents' mental health[18], while in relatively small nations with islands[53] or sparsely populated areas like Canada[40], the effect of proximity is not significant.

(2) Availability

The availability of urban blue spaces is significantly positively correlated with residents' general mental health (*SMD* = 0.16, $p < 0.0001$) and positive psychology (*SMD* = 0.91, $p < 0.0001$) (Table 5). In other words, residents living in areas with blue spaces nearby or more blue spaces have better self-assessed mental health and stronger happiness. Studies suggest that the availability of urban blue spaces may have a greater effect in enhancing residents' mental health through improved environmental perception and physical activities[49][58], compared with the effect of green spaces[45]. Additionally, studies have found that childhood residential environments would affect their mental health in adulthood. A study in Denmark found that a higher proportion of blue spaces within 1 km of childhood residences was associated with greater calmness in adulthood, though the effect on mental health was not

Table 4: Effect size aggregation results of the proximity to urban blue spaces on residents' mental health (*n* = 11)

		SMD (95%CI)	Heterogeneity test			Statistical test		Literature
			I^2	Chi^2	*Df*	*z*	*p*	
General mental health		0.33[0.16, 0.50]	81%	10.44	2	3.82	0.0001	Refs. [10][18][35]
Positive psychology	Subjective happiness	0.15[–0.07, 0.36]	98%	141.34	3	1.35	0.18	Refs. [32][40][53][63]
	Life satisfaction	0.19[0.13, 0.26]	0%	0.73	1	5.79	< 0.00001	Refs. [13][18]
	Total	0.15[–0.01, 0.30]	97%	41.06	4	2.73	0.006	—
Negative psychology	Depression	–0.31[–0.75, 0.4]	91%	32.89	3	1.00	0.17	Refs. [10][17][48][60]
	Anxiety	–0.44[–0.91, 0.03]	—	—	—	1.83	0.07	Ref. [17]
	Total	–0.33[–0.72, 0.06]	89%	37.91	4	1.67	0.10	—

Table 5: Effect size aggregation results of the availability of urban blue spaces on residents' mental health (*n* = 13)

		SMD (95%CI)	Heterogeneity test			Statistical test		Literature
			I^2	Chi^2	*Df*	*z*	*p*	
General mental health		0.16[0.08, 0.24]	100%	1,106.70	5	4.04	< 0.0001	Refs. [10][18][35][45][49][62]
Positive psychology	Subjective happiness	1.02[0.26, 1.79]	72%	7.15	2	2.62	0.009	Refs. [53][60][61]
	Life satisfaction	0.87[0.48, 1.26]	—	—	—	4.38	< 0.0001	Ref. [60]
	Total	0.91[0.47, 1.35]	58%	7.21	3	4.06	< 0.0001	—
Negative psychology	Depression	–0.33[–0.72, 0.06]	99%	422.21	6	2.52	0.01	Refs. [10][12][20][21][36][60][61]

statistically significant, the regression coefficient was positive[62]. Consistent outcome has been validated with studies in China[14][60], England[10], Bulgaria[50], etc. Besides, some studies examine the impact of urban blue spaces around residential areas and travel paths by considering residents' spatio-temporal behaviors. For example, a study in China found that urban blue spaces around daily travel paths (≤ 200 m) had a more significant impact on individual mental health[14], while a study in the Netherlands did not find significant difference in health effects with urban blue spaces around residential areas and travel paths[20]. Overall, the availability of urban blue spaces is confirmed to be beneficial for mental health, but the specific impact may vary due to geographical and individual behavioral variety.

Furthermore, the meta-analysis results suggest that the effect of the accessibility of urban blue spaces on psychological disorders such as depression is not significant (*SMD* = –0.33, $p = 0.01$), and the research findings vary. Although some studies have found positive effects of urban blue spaces in specific cases—for example, a study in Scotland found that elderly community members with high freshwater coverage had lower frequencies of antidepressant intake[12]; a study in China revealed that the residents living within a 300-m buffer to blue spaces reported significantly less depression[60]—most studies did not find significant effects. Examples included the studies about children in USA[47] and New Zealand[53], adults in the Netherlands[20] and Spain[36], and among cohort of Alzheimer and families in Spain[17]. These findings suggest that while urban blue spaces may benefit certain groups, their effects on preventing or alleviating mental disorders may be limited, requiring further research to explore the influencing mechanisms and conditions.

(3) Visibility

Due to data availability constraints, only four studies explored the association between the visibility of urban blue spaces and residents' mental health. Although the meta-analysis did not cover these studies for effect size conversion reasons, they all found that the visibility of urban blue spaces not only helps residents' self-reported mental health but also has significant positive effects on negative psychology. Daniel Nutsford is one of the earliest scholars focusing on the health effects of the visibility of urban blue space. His study in New Zealand found that residents with ocean views had lower psychological stress even when controlling other factors such as proximity to urban blue spaces[46]. Similar conclusions were validated in a study in Ireland, where residents with high visibility of coastal views from their homes had a lower risk of depression, and visibility had a more significant effect than proximity[48]. Recently, Chinese scholars have also analyzed the effects of blue space visibility on residents' mental health based on street view images in Beijing[54] and Guangzhou[15], finding that a higher proportion of blue space area in the images can reduce the risk of depression in the elderly and improve mental health.

4.2.2 Impact of Urban Blue Space Characteristics on Residents' Mental Health Through Individual-based Measurement

In the selected literature, 25 individual-based studies explored the association between urban blue space characteristics and residents' mental health by examining individual behavioral characteristics (e.g., visit frequency, types of blue spaces visited, visiting distance) and exposure types. Due to the diverse measurement methods of these studies, meta-analysis is not feasible; instead, this paper qualitatively summarized these studies in both aspects.

(1) Individual behavioral characteristics

Scholars have found that individuals who frequently visit urban blue spaces (at least once a week) generally have higher subjective well-being[13][32] and lower mental distress[61] and inattention[42]. Visiting urban blue spaces more frequently in childhood also positively influences mental health in adulthood[65]. Different types of urban blue spaces lead to varied mental health effects. For instance, a study in England found that frequent visits (more than twice a month) to rivers, canals, and seas are positively correlated with better mental health, while frequent visits to lakes show no significant correlation[68]. This may be due to the different spatial experiences and physical activities provided by various types of urban blue spaces. In addition to visit frequency, studies indicate that whether residents visit urban blue spaces[55], the visibility of blue spaces, the likelihood of visiting blue spaces during the pandemic[63], and the characteristics of blue spaces along recreational routes[64] are important factors affecting mental health. In addition, although beaches, harbor areas, and other waterside areas can significantly promote restorative benefits[39][41], blue spaces' associations with depressive symptoms and stress are debatable[20][66], especially for the areas with a low amount of blue spaces where green spaces may overwhelm blue spaces in alleviating negative psychology[51].

Experimental studies, compared with observational studies such as cross-sectional analysis, often evaluate the benefits of physical activities (e.g., walking[59], surfing[43]) in urban blue spaces on mental health. These studies compare changes in physiological indicators (e.g., pulse, blood pressure) before and after activities, revealing that physical activities in urban blue spaces can promote restorative experience[34] and perception[64], and

psychological improvement[33][52]. For example, a study in Spain found that members of the experimental group who walked in urban blue spaces reported significantly enhanced well-being and mood after the activity[59]. This positive effect is not evident in the general population but also in individuals with severe psychological disorders. For instance, PTSD patients who participated in surfing sessions showed significant symptom relief[43]. Similar findings have been validated in studies conducted in Spain[33], USA[34], and UK[56]. Experimental studies also found that different types of urban blue spaces have varying effects on residents' restoration. For example, the restorative capability of beaches is about 30% higher than that of harbors[69].

(2) Exposure types

Only a few studies have evaluated the impact of exposure types to urban blue spaces on residents' mental health. For instance, a study in Hong Kong, China found that intentional exposure to blue spaces was positively correlated with higher well-being, while indirect exposure (viewing from home) was positively correlated with better self-perceived physical health but had no significant association with mental health[32]. A study in Guangzhou, China discovered that incidental exposure to blue spaces from travel had more significant mental health benefits than indirect exposure[14]. Additionally, short-term intentional exposure to urban blue spaces positively impacts mental health. Studies in UK indicated that residents who recently and intentionally visited blue spaces like rivers and canals reported higher life satisfaction and better mental health[38][67]. Another study in Spain compared the effects of intentional visits to urban parks and beaches on psychological restoration, finding that blue space visitors reported higher relaxation and attention restoration[11]. These findings suggest that different exposure types to urban blue spaces have varying impacts on residents' mental health.

5 Conclusions and Discussion

This paper, as a meta-analysis, focuses on the effect of urban blue space characteristics on residents' mental health, systematically reviewing the measurement indicators, research models, and mental health effects among relevant literature, with main findings as follows. First, urban blue space characteristics can be measured from space-based dimension (i.e., proximity, availability, visibility) and individual-based dimension (e.g., individual visit characteristics, exposure types). Second, the impact of urban blue space characteristics on mental health is mainly measured by general mental health, positive psychology (self-reported well-being, perceived restorativeness, and positive emotions), and negative psychology (negative emotions and mental disorder). Third, the effect of urban blue space characteristics on residents' mental health varies significantly across studies, particularly concerning psychological disorders such as depression and stress disorders. Specifically, the proximity to urban blue spaces positively affects general mental health and positive psychology, while the accessibility of blue spaces is significantly positively correlated with general mental health and positive psychology; although factors like visibility, visit frequency, and exposure types influence mental health, related research is still limited, necessitating further exploration in the future.

Existing research on the health benefits of natural environments often focuses on green spaces. This study's findings reveal that blue spaces are equally valuable for residents' mental health. By quantifying the effects of urban blue space characteristics on general mental health and positive psychology, this meta-analysis supports the view that blue spaces can positively influence mental health. In terms of the effects of green spaces on mental health, researchers found that exposure to green spaces effectively alleviates negative psychology such as anxiety and depression[23]. This study's results show that the proximity to urban blue spaces has a similar effect size to green spaces in alleviating anxiety, while the impact of proximity and accessibility on depression and anxiety remains controversial. Blue spaces are important components in most cities—the median distance of urban residents to freshwater bodies is only 3.1 km[7]—thus, analyzing the health effects of urban blue spaces and leveraging their health-promoting capabilities are significant for the construction of healthy cities.

Although existing research has yielded substantial results, future studies should focus on the following aspects.

1) Increasing empirical research in developing countries and inland cities. The health benefits of urban blue spaces vary significantly in different geographical contexts. Most current studies are conducted in developed countries in Europe and America, while fewer studies in developing countries—limited empirical research in China also focuses on coastal cities like Guangzhou and Hong Kong, with insufficient attention to inland cities. In the future, empirical studies should be conducted in more areas, especially in developing countries and inland cities, to enrich the evidences on the mental health benefits of urban blue spaces.

2) Exploring refined measurement of urban blue space and mental health indicators. Current measurements of the characteristics of urban blue spaces are mostly based on large-scale land use data or remote sensing data, ignoring the impact

of numerous small-scale urban blue spaces on residents' mental health. Ponds and lakes, for example, are the most commonly found water bodies on the earth, which are crucial for freshwater biodiversity and playing a significant role in ecosystem services[75]. Moreover, more experimental research should be performed with physiological mental health data (e.g., heart rate, blood pressure) to refine the methods and systems of measurement indicators.

3) Expanding research on the effect of urban blue space characteristics on mental health. First, current studies mainly focus on a single type of blue space (e.g., oceans or inland blue spaces), and future studies need to explore the differences of varied inland blue space types (e.g., rivers, lakes, ponds) in health effects. Second, most studies examine the impact of quantitative indicators of blue spaces (e.g., proximity, availability) on mental health, and future research should also explore the impact of qualitative factors of blue spaces on mental health. Third, evaluations on urban blue space characteristics are often conducted from either space-based or individual-based dimensions, and future studies should combine travel data to comprehensively analyze the differences of mental health effects of blue space characteristics.

4) Deepening the exploration of influencing mechanisms. Current research rarely explores the influencing mechanisms of urban blue spaces on residents' mental health, especially the unique mechanisms of blue spaces own. Future research should put more efforts in investigating the effects of factors such as sound environment, physical activity, and social interaction.

Competing interests | The authors declare that they have no competing interests.

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城市蓝色空间对居民心理健康影响的荟萃分析

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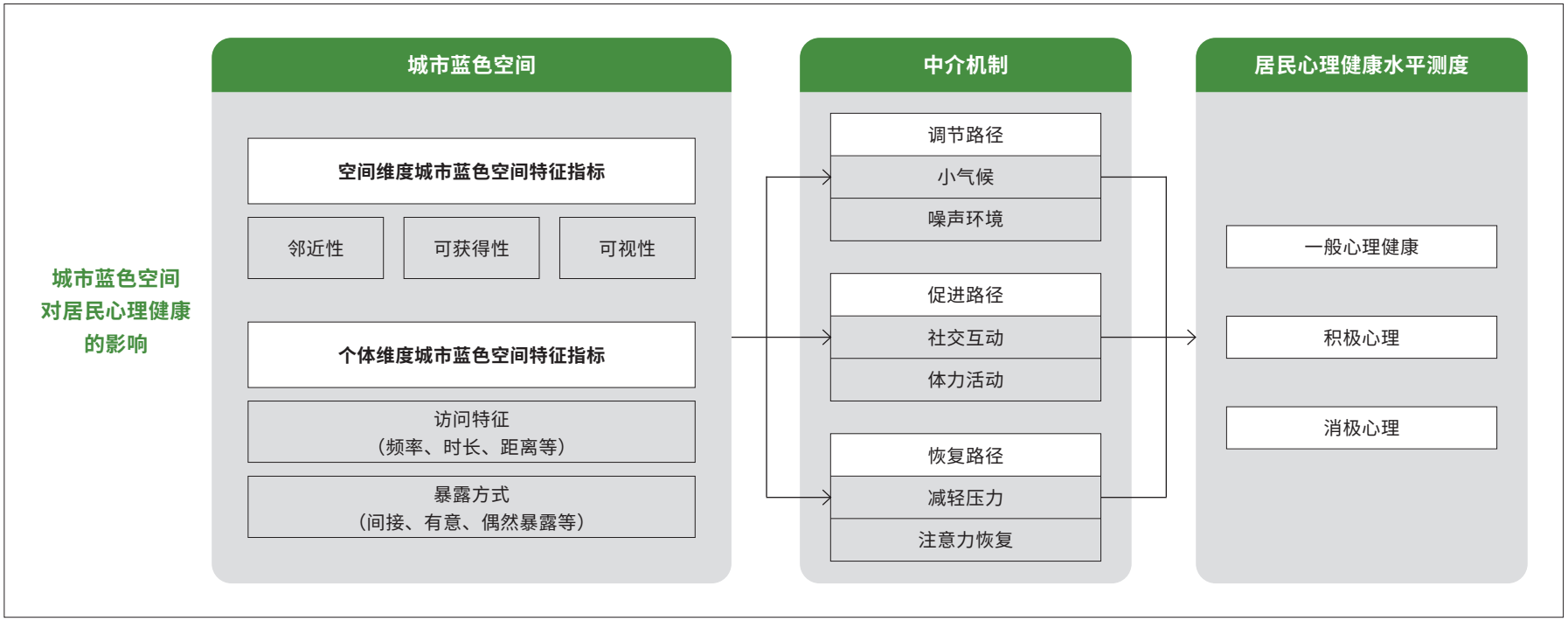
图文摘要



摘要

城市蓝色空间对居民心理健康的影响已引起国内外学者的高度关注，对这类空间健康效应的量化评估是当前的研究热点。基于此，本研究在回顾城市蓝色空间与居民心理健康理论的基础上，通过系统地审查Web of Science、知网等数据库的文献，筛选出47篇关键文献进行荟萃分析，深入探讨城市蓝色空间对居民心理健康影响的测度指标和研究模型，并对效应量进行标准化。研究发现：1）城市蓝色空间特征的测度指标主要分为基于空间和基于个体两个维度；2）心理健康水平的测度主要涵盖一般心理健康、积极心理和消极心理三类；3）蓝色空间的邻近性在提升居民的一般心理健康和积极心理方面具有显著积极效应；4）蓝色空间的可获得性与一般心理健康和积极心理呈显著正相关；5）虽然有研究证实蓝色空间可视性、访问频率和暴露方式等因素对心理健康有影响，但相关研究较为有限；6）关于蓝色空间对消极心理影响的研究存在较大争议，特别是在抑郁等心理障碍的影响上，不同研究结果差异显著。本文的研究结果可为未来相关研究及健康城市建设提供指引。

关键词

城市蓝色空间；心理健康；荟萃分析；环境暴露；效应量

文章亮点

- 对城市蓝色空间之于居民心理健康的影响进行了荟萃分析
- 明晰了城市蓝色空间对居民心理健康的影响相关研究的测度指标和研究模型
- 量化了城市蓝色空间邻近性、可获得性和可视性等特征对居民心理健康影响的效应量
- 城市蓝色空间对消极心理的影响存在争议，特别是在抑郁等心理障碍的影响上，不同研究结果差异显著

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1 引言

快速城镇化在有效提高经济发展水平的同时，也带来了一系列的环境和社会问题，威胁居民身心健康[1]。统计数据显示，中国居民抑郁风险比率高达10.6%[2]。改善全民心理健康已成为联合国可持续发展目标之一[3][4]，表明心理健康已成为全球关注的议题。“城市蓝色空间”（urban blue space）通常指城市中所有可见的地表水域[5]，包括海洋、湖泊等自然水体，以及喷泉、池塘等人工水体[6]。作为城市自然环境的重要组成部分，全球约一半的人口生活在距蓝色空间3km的范围内[7]。这些空间不仅能够减缓热岛效应、促进社交活动，还被广泛认为有助于缓解心理压力，进而提升心理健康水平[8][9]。因此，探讨城市蓝色空间对心理健康的影响对于未来城市规划设计工作意义重大。

学者们越来越关注城市蓝色空间与心理健康之间的联系，但研究结果表现出一定的差异。一些研究指出，居住地靠近城市蓝色空间的居民往往拥有更好的心理健康状况[10]、更强的压力恢复力[11]，以及较低的抑郁药物服用率[12]；定期访问城市蓝色空间的人具有更高的主观幸福感[13]；居住地周围有更多蓝色空间[14]或能看见蓝色空间[15]的城市居民，也报告了更积极的心理健康结果。相较于城市绿色空间，一些研究认为蓝色空间对健康的促进作用更加明显[16]，因为蓝色空间能提供多样化的水上活动，带来心理裨益[17]。然而，也有研究指出，由于地理环境、研究设计和个体差异等因素，未能发现城市蓝色空间与心理健康指标之间的显著关系[18]。另外，城市蓝色空间对不同类型心理健康的影响也不尽相同[19]。例如，可以通过减轻压力路径降低焦虑，但对抑郁等其他心理疾病的效果并不明显[17][20][21]。鉴于这些研究差异，有必要对相关研究进行系统回顾，梳理现有理论框架，并讨论研究中的不足和争议。

现有少量研究对城市蓝色空间的心理健康效应进行了综述，但多侧重于定性归纳，对未来研究方向的指导和参考仍然有限。相较于传统的定性综述，荟萃分析通过制定系统、严格的文献检索标准和筛选条件，并依据文献异质性特征选择分析模型，从而呈现更为可靠和准确的结论[22]。由于环境与健康领域的研究成果多因研究设计、样本量等不同而存在差异，近年来逐渐引入荟萃分析以减少单个研究对结论的影响[6][23][24]。其中，尼亚姆·史密斯等人通过筛选25篇研究进行荟萃分析，揭示了蓝色空间对居民肥胖率、心理健康的积极影响[6]。然而，这项研究并未细分心理健康的类型，且其文献搜索范围仅截至2019年8月。鉴于近年来有关城市蓝色空间对居民心理健康影响的研究不断涌现，有待展开更全面的定量综述，以更精确地阐明城市蓝色空间的心理健康效应。

基于此，本研究立足于现有城市蓝色空间与心理健康的理论基础，利用WoS（Web of Science）、Medline、中国知网及万方数据库，筛选并分析了2000年1月1日~2022年12月31日发表的实证研究文献。研究旨在揭示：1）影响居民心理健康的城市蓝色空间特征，涵盖的心理健康类型及测度方法；2）城市蓝色空间各类特征对心理健康影响的效应量。本研究将为改善居民心理健康的城市规划设计实践提供科学依据。

2 基础理论与研究框架

城市蓝色空间与心理健康研究作为环境与健康领域的新兴分支，融合了健康地理学、景观生态学、环境心理学等多学科理论基础和知识体系。尽管不同学科的侧重点有所差异，但它们共同为深入理解城市蓝色空间对居民心理健康的影响机制提供了理论支持[8]。

具体而言，健康地理学相关研究以社会生态学理论为核心，将城市蓝色空间视为城市建成环境系统中的组成要素[25]，可通过直接或间接路径对居民心理健康产生影响[26]。相关研究多从宏观尺度（如全国、区域、城市等）展开，采用全国性标准化大样本调查数据，以社区为基本分析单元，着重探究城市蓝色空间对居民心理健康的影响在不同社区类型中的异质性。

景观生态学相关研究以生态系统服务理论为支撑，从供需视角出发，探讨城市蓝色空间与居民心理健康的关系，并提出了反映自然环境健康效益的生态系统服务评估理论模型[27]。该理论将城市蓝色空间等自然环境要素视作城市生态系统的重要组成部分，在生态系统服务的供需

关系体系中，城市蓝色空间是供给方，而居民是核心需求方，环境“暴露”和“接触”是实现供需有效对接的主要方式[28]。即居民通过各种感官方式（如视觉、听觉等）与城市蓝色空间接触并开展活动，达到促进心理健康的目的。相关研究多围绕中、微观尺度（如社区、单个或若干个典型蓝色空间等）展开，侧重于探讨不同城市蓝色空间类型对居民心理健康影响的差异。

值得注意的是，环境心理学中的“注意力恢复理论”和“亲生命假说”是广为探讨的基础理论。其中，注意力恢复理论由美国环境心理学家斯蒂芬·卡普兰和瑞秋·卡普兰提出，认为自然环境要素（包括蓝色空间）相较于人工建成环境，具有精神远离感、延展性、神秘性等八种治愈性特征，有助于定向注意力的恢复[29][30]。而亲生命假说则强调人类天生对自然具有亲近感，认为自然具有治愈能力对改善人类身心健康有显著效果[31]。与景观生态学的研究类似，环境心理学的研究亦聚焦中、微观尺度，但其研究方法多为实验性研究，侧重探究不同城市蓝色空间的特征要素、居民接触方式等对心理健康影响的差异。

尽管不同学科研究的侧重点有所不同，但它们都强调了城市蓝色空间对居民心理健康福祉的重要意义，并关注于城市蓝色空间的邻近性、可获得性、可视性这类空间维度指标，以及居民访问特征、暴露方式这类个体维度指标对居民心理健康的影响。这些研究中探究的影响路径可归纳为以下三类[8][32]：1）调节路径：城市蓝色空间通过调节微气候（如降低温度、增加湿度等），改善居民的心理感知和情绪状态[33]；同时，水体产生的流水声、喷泉声等能够改善声环境，从而提高心理舒适度[34]。2）促进路径：城市蓝色空间通过提供运动、休闲等有益于健康行为的场地，促进居民心理健康[17][35]~[37]；城市蓝色空间亦有助于促进社会交往，增强归属感和邻里凝聚力等，对居民心理健康产生积极影响[38]。3）恢复路径：城市蓝色空间作为自然环境的重要类型，可减轻居民心理压力、恢复其注意力，进而促进心理健康[8]（图1）。

3 数据与方法

3.1 数据来源

本文以中国知网和万方数据库为中文文献的检索源，以WoS、Medline为英文文献的检索源，构建了包含“蓝色空间”（blue space）、“居民”（resident），以及“心理健康”（mental health）三个类别的中英文主题词库（表1）。通过组合关键词进行文献检索，时间范围设定为2000年1月1日至2022年12月31日，领域限定为“城市研究”（Urban Studies）、“地理学”（Geography）、“环境科学”（Environmental Sciences）等相关领域。在此基础上，对WoS数据库检索结果中的“高被引文献”（highly cited papers）进行二次进阶检索，共搜集到期刊文献5 765篇（图2）。

表1：文献检索主题词概览

主题词类别	语言	主题词
蓝色空间	中文	蓝色空间；江；河；湖；海；滨水；海岸；河岸；湿地
	英文	Blue space; river; lake; sea; ocean; waterfront; coastal; coast; riparian; wetland
居民	中文	居民；人；公众；老人；儿童；青少年；学生
	英文	Resident; people; public; old; children; teenager; student
心理健康	中文	心理健康；抑郁；焦虑；幸福；情绪；压力；强迫症
	英文	Mental health; depression; anxiety; wellbeing; emotion; stress; obsessive-compulsive

随后，本研究通过两轮严格的文献筛查确定了有效样本。初步筛查利用Rayyan工具检阅文献标题、摘要和关键词，剔除重复和不相关的研究，共获得481篇文献，其中英文文献432篇，中文文献49篇。第二轮筛查对全文进行细致审阅，依据四项标准挑选实证研究：1）纳入采用截面分析、纵向分析、随机交叉实验或自身对照实验的实证研究，剔除定性研究；2）保留核心研究对象为城市的自然和人造蓝色空间的研究，剔除将蓝色空间作为中介因素或将蓝、绿空间混合的研究；3）将研究范围限定为城市区域，剔除有关微量元素与微生物的研究；4）文献全文可获取。最终筛选出47篇符合条件的文献[10]~[15][17][18][20][21][32]~[36][38]~[69]，其中英文文献45篇，中文文献2篇（表2）。

3.2 研究方法

荟萃分析通常包括定性总结和定量合成两部分[6]。定性总结是对纳入研究的全面描述，包括研究设计、指标测度、样本特征等内容；定量合成是对效应量的合并，效应指标可以是标准化均值差（*SMD*）、相关系数等；这些指标对应的数值大小则为效应量，表征研究中两个变量之间关系的强度值。健康效应量即自变量对健康的影响程度；在环境健康领域的荟萃分析中，多选用*SMD*作为效应量指标[23][24]。定量合成包含两个步骤：1）效应量的转换：依据效应量转换计算器Psychometrica将部分纳入文献的效应量转化为*SMD*；2）效应量的合并：运用Revman5.4软件合并样本量和转换后的*SMD*值，由于文献中各研究对象心理健康维度的异质性，即有较高的I^2（荟萃分析的统计指标，用以衡量异质性程度），

表 2：纳入荟萃分析的文献列表

文献序号	发表年份	案例所在国家／地区	研究对象	城市蓝色空间特征测度指标	心理健康水平测度指标	研究模型
39	2010	芬兰	成年人	受访者最喜欢的空间类型（蓝色空间等）；访问频率；访问时长	恢复性感知	截面分析
18	2013	英格兰	成年人	居住地距蓝色空间的欧式距离	一般心理健康；生活满意度	纵向分析
40	2013	加拿大	少年儿童（学生）	（学校 5km 缓冲区内）是否存在蓝色空间	主观幸福感	截面分析
41	2013	英格兰	成年人	访问时长；访问距离	恢复性感知	截面分析
42	2014	西班牙	少年儿童（学生）	全年访问天数	注意力缺陷／多动症（ADHD）症状	截面分析
43	2014	美国	成年人（退伍军人）	为期 5 周、每周一次的冲浪运动	创伤后应激障碍；抑郁症状	自身对照实验
36	2015	西班牙	成年人	（居住地 300m 缓冲区内）是否存在蓝色空间	一般心理健康；是否感知到抑郁或焦虑；是否拜访心理专家；是否摄入药物	截面分析
44	2015	苏格兰	成年人（科学园区员工）	工位是否可见水景	主观幸福感	截面分析
45	2016	荷兰	成年人	（居住地 1km 缓冲区内）蓝色空间覆盖率	精神疾病；自评心理健康	截面分析
46	2016	新西兰	成年人	居住网格内的蓝色空间可见性	感知压力水平	截面分析
13	2017	英格兰	成年人	社区内是否可见蓝色空间；访问频率；昨天是否访问蓝色空间	主观幸福感	截面分析
33	2017	西班牙	成年人（有心理困扰迹象者）	在蓝色空间开展身体锻炼和社交活动	一般心理健康；生理指标（血压、心率、唾液皮质醇）	随机交叉实验
17	2018	西班牙	成年人（阿尔茨海默病患者和家人）	（居住地 100m、300m、500m 缓冲区内）是否存在蓝色空间	感知焦虑；感知抑郁	截面分析
21	2018	荷兰	全年龄段（精神障碍患者）	（居住地 300m 缓冲区内）蓝色空间覆盖率	精神障碍患者住院时长	截面分析
47	2018	美国	少年儿童	距蓝色空间的欧氏距离；（居住地 250~1 250m 缓冲区内）是否存在蓝色空间	重度抑郁症发病率	截面分析
48	2018	爱尔兰	老年人	距蓝色空间的欧氏距离；居住地可见的蓝色空间面积占比	感知抑郁	截面分析
49	2018	保加利亚	青年（学生）	距蓝色空间的欧氏距离；（居住地 300m 缓冲区内）是否存在蓝色空间	一般心理健康	截面分析
50	2018	保加利亚	青年（学生）	（居住地 100m、300m、500m 缓冲区内）是否存在蓝色空间	一般心理健康	纵向分析

（续表见下页）

表 2：纳入荟萃分析的文献列表（接上表）

文献序号	发表年份	案例所在国家／地区	研究对象	城市蓝色空间特征测度指标	心理健康水平测度指标	研究模型
51	2018	德国	成年人	访问频率；感知的访问距离	一般心理健康	截面分析
52	2018	瑞士	成年人	实地观赏	生理参数；感知压力水平；注意力恢复	自身对照实验
10	2019	英格兰	成年人	距蓝色空间的欧式距离	一般心理健康；感知焦虑与抑郁	截面分析
32	2019	中国香港	老年人	蓝色空间质量（受访者对安全、野生动物、清洁、设施的评分）；暴露类型；访问频率；访问距离；活动强度；访问时长	主观幸福感	截面分析
35	2019	英格兰	成年人	距蓝色空间的欧式距离；有无淡水	一般心理健康	截面分析
53	2019	新西兰	少年儿童（学生）	距蓝色空间的欧氏距离；居住街区内是否存在内陆蓝色空间	主观幸福感；感知抑郁	截面分析
54	2019	中国大陆	老年人	街景图片中蓝色空间像素占比的均值；归一化差分水体指数（NDWI）	老年抑郁症	截面分析
55	2019	新加坡	少年儿童（学生）	是否访问蓝色空间	瞬时主观幸福感	截面分析
56	2019	英国	成年人	连续六周每周参加两次湿地活动	主观幸福感；感知压力水平；感知焦虑	自身对照实验
11	2020	西班牙	成年人	访问距离；访问频率；访问时长	恢复性感知	截面分析
15	2020	中国大陆	成年人	街景图片中蓝色空间像素占比的均值；（居住地 1.5km 缓冲区内）蓝色空间覆盖率	一般心理健康	截面分析
57	2020	中国大陆	老年人	距蓝色空间的欧式距离；NDWI	一般心理健康	截面分析
58	2020	中国大陆	老年人	距蓝色空间的欧式距离；（居住地 1km 缓冲区内）蓝色空间覆盖率、人均蓝色空间面积和蓝色斑块破碎化指数	一般心理健康	截面分析
59	2020	西班牙	成年人	在蓝色空间步行（连续 3 周、每周 4 天、每天 20 分钟）	主观幸福感；一般心理健康；情绪障碍；生理参数（血压、心率）	随机交叉实验
12	2021	苏格兰	老年人	距蓝色空间的欧氏距离;（居住地 800m、1.6km 缓冲区内）蓝色空间覆盖率	抗抑郁药物使用频率	截面分析
14	2021	中国大陆	成年人	（居住地 500m 缓冲区和日常出行路径 200m 缓冲区内）蓝色空间覆盖率	主观幸福感	截面分析
20	2021	荷兰	成年人	（居住地 50m 和 100m 缓冲区内）蓝色空间覆盖率	感知抑郁	截面分析

（续表见下页）

表 2：纳入荟萃分析的文献列表（接上表）

文献序号	发表年份	案例所在国家／地区	研究对象	城市蓝色空间特征测度指标	心理健康水平测度指标	研究模型
34	2021	美国	青年（学生）	在蓝色空间步行（与在城市环境步行对比）	恢复性体验	随机交叉实验
38	2021	英国	成年人	访问频率	主观幸福感；生活满意度	截面分析
60	2021	中国大陆	全年龄段	距蓝色空间的欧式距离；（居住地 300m、500m、1km 缓冲区内）蓝色空间面积	感知抑郁；主观幸福感	截面分析
61	2021	英国、美国等 18 个国家／地区	成年人	（居住地 1km 缓冲区内）蓝色空间覆盖率；过去 4 周访问频率；与自然的紧密度感知	积极情绪；心理困扰；是否服用抑郁药	截面分析
62	2021	丹麦	成年人（献血者）	（居住地 500m、1km、3km 缓冲区内）蓝色空间覆盖率	一般心理健康	纵向分析
63	2021	比利时	成年人	居住地是否为沿海城市；访问频率	主观幸福感	截面分析
64	2021	中国大陆	少年儿童	公园内活动路径上的蓝色空间环境特征	恢复性感知	截面分析
65	2022	英国、美国等 18 个国家／地区	成年人	童年接近蓝色空间的经历（可达性、监护人对其在蓝色空间活动的态度、访问频率）；成年后访问蓝色空间的频率	主观幸福感	截面分析
66	2022	美国	成年人	访问频率；访问距离；访问时长	感知压力水平；主观幸福感；生活满意度	截面分析
67	2022	英格兰和威尔士	成年人	当前所在地是否可以看到水体；过去 24 小时是否访问蓝色空间	一般心理健康	截面分析
68	2022	英国	成年人	访问距离；访问频率；访问时长	主观幸福感	截面分析
69	2022	比利时	青年（学生）	对蓝色空间照片进行打分	恢复性感知	截面分析

注

因不同国家和地区、不同研究对年龄划分存在差异，为了便于样本统计，本研究依据纳入文献样本特点，将研究对象划分为：1）少年儿童：0~18 岁；2）青年：18~35 岁；3）成年人：18 岁及以上；4）老年人：样本年龄主要为 50 岁及以上；5）全年龄段群体，样本年龄涵盖多个年龄段。

故采用随机效应模型进行分析[23][70]。受研究设计差异性、效应指标转换可行性等因素影响，并非所有纳入的文献都适合进行定量合成，故本研究仅对符合要求的文献进行效应量合成，对其他文献进行定性总结。

4 结果分析

统计结果显示（图3），在年份分布方面，文献发表数量自2010年以来呈波动上涨趋势，其中2018~2022年为发文量高峰期，发布的文献数量占总量的74.5%。在研究对象方面，针对成年人的研究数量最多，达29项；聚焦于少年儿童和老年人的研究各有6项；聚焦于青年的研究4项；另有针对全年龄段群体的研究2项。在地理分布上，在欧洲进行的研究有29项、亚洲9项、北美洲5项、大洋洲2项，另有2项跨洲研究。

4.1 城市蓝色空间特征与居民心理健康水平的测度与研究模型

4.1.1 城市蓝色空间特征的测度

现有文献对城市蓝色空间特征的测度可划分为基于“空间”

（space-based，即居住地或办公地）维度和基于“个体”（individual-based，即受访者）维度两类。其中，基于空间和个体维度进行测度的研究各有21项，另有5项研究同时从空间和个体维度进行测度。

（1）基于空间维度的测度

基于空间维度的测度通常使用宏观数据（如土地利用和交通数据）来确定居民的城市蓝色空间暴露水平。具体而言，基于空间的测度通常假设居民全天不移动，以居住地或工作地周边缓冲区内（缓冲区范围多设定为0.3~1.5km）蓝色空间的测度结果来表征居民对蓝色空间的暴露水平。这类测度的观测指标包括邻近性、可获得性和可视性。邻近性指居住地是否沿海[63]、分析单元人口质心到城市蓝色空间的欧式距离[10][12][13][18][35][47]~[49][53][57][58][60]；可获得性指缓冲区内是否存在城市蓝色空间[17][36][40][47][49][50]、蓝色空间覆盖率[12][14][15][20][21][45][58] [60]~[62]或人均城市蓝色空间面积[58]；可视性则通常依据土地利用和高程数据测量特定位置的城市蓝色空间可视率[46][48]。随着人工智能、大数据等技术的发展，一些学者已开始利用街景图像和深度学习技术来测量视野范围内城市蓝色空间占比[15][54]。

然而，从静态空间的角度来测度居民的城市蓝色空间暴露水平具有一定的局限性。不确定地理背景问题[71][72]指出，现有的研究多以社区、人口普查片区或邮政编码片区等作为分析单元，其结果可能会因地理单元的不同划分而有所不同[73]。同时，邻里效应平均问题[74]也表明，静态的测度方法无法捕捉到个体访问特征、经济状况及暴露方式等因素带来的差异，导致测度结果与实际暴露水平存在出入。

（2）基于个体维度的测度

基于个体维度的测度多使用问卷数据来评估居民主动访问城市蓝色空间的行为特征。这类测度通过测量居民个体访问城市蓝色空间的行为特征、暴露方式等，精确地捕捉居民的城市蓝色空间暴露水平。例如，行为特征多关注于是否可见[44]、是否访问[13][41][55][67]、访问频率 / 数[11][13][32][38][39][42][51][61][63][65][66][68]、出行距离[11][32][51][66][68]、访问时长[11][32][39][66][68]及在蓝色空间中进行的活动类型[33][34][43][52][56][59][64]等对心理健康的影响；暴露方式关注于间接暴露（从家中可见）、偶然暴露（通勤等出行途中可见）、故意暴露（目的性访问[32]）及虚拟暴露（观看蓝色空间照片[69]）等不同暴露方式对心理健康的影响。

（3）同时基于空间和个体维度的测度

一些研究综合考虑了空间和个体维度，如通过城市居民的活动日志追踪他们的时空行为轨迹，综合计算居住区及出行路径周边的城市蓝色空间覆盖率[14][20]，或通过问卷调查获取居民的住址和城市蓝色空间访问情况，全面评估个体的城市蓝色空间暴露水平[13][61][63]。

4.1.2 居民心理健康水平的测度

在所选文献中，居民心理健康水平的测度主要分为三类：一般心理健康、积极心理和消极心理（表3）。一般心理健康多通过综合性问卷量表来评估个体的心理健康状况。积极心理涉及主观福祉（含主观幸福感和生活满意度）、恢复性感知和积极情绪三方面；而消极心理则包括压力、沮丧等消极情绪，以及抑郁、广泛性焦虑等心理障碍。此外，也有少量研究通过住院时间、抑郁症发病率等医疗统计分析，以及测度血压和心率等生理指标的方法，从不同角度获取居民心理健康数据。

4.1.3 研究模型

在研究模型方面，所选文献主要包括观察性研究和实验性研究两类。观察性研究一般采用截面分析或纵向分析，通过多元线性回归[11]、泊松回归[48]、结构方程模型[49]和中介效应模型[57]等模型探究城市蓝色空间特征对居民心理健康的影响效应，并分析其空间异质性。截面分析易于获取数据，注重探讨相关性。纵向分析虽然数据获取较难，但能更深入解析影响机制。

实验性研究通常采用随机交叉[33][34][59]或自身对照[43][52][56]的实验方法，要求受访者以虚拟（如观看照片[69]等）或实际体验（冲浪[43]、步行[34]等）

表 3：居民心理健康水平测度方法概览

心理健康	测度方法	代表样本文献
一般心理健康	一般健康问卷（GHQ-12）	参考文献 [10][15][18][33][35][36][50]
	心理健康清单（MHI-5，属健康调查 SF-36 量表中心理健康的子量表）	参考文献 [45][57]~[60][66]
	身体健康调查简表（SF-12）	参考文献 [51][62]
	情绪状态量表（POMS）	参考文献 [33][59]
	自编测度一般心理健康的问题	参考文献 [67]

（续表见下页）

表 3：居民心理健康水平测度方法概览（接上表）

心理健康		测度方法	代表样本文献
积极心理	主观福祉	世界卫生组织五项幸福指数量表（WHO-5）	参考文献 [14][32][38][53][59][61][65][68]
		（短版）沃里克 – 爱丁堡心理幸福感量表（SWEMWBS/WEMWBS）	参考文献 [44][56][63]
		英国国家统计局制定的 4 个主观幸福感问题（含生活满意度的单项问题）	参考文献 [13][59][60]
		单项生活满意度的问题	参考文献 [18][66]
		坎特里尔阶梯（Cantril Ladder）	参考文献 [40]
	恢复性感知	恢复性感知量表（PRS）	参考文献 [11][64][69]
		恢复结果量表（ROS）	参考文献 [11][39]
		短版恢复性感知量表（SRRS）	参考文献 [34]
		自编测度恢复性感知的问题	参考文献 [41]
	积极情绪	积极和消极情绪量表（PANAS）中评估积极情绪的问题	参考文献 [56]
	其他	让被试者在感到快乐的瞬间按下按钮，以表征其瞬时幸福感	参考文献 [55]
消极心理	消极情绪	压力感知量表（PSS）	参考文献 [56][66]
		凯斯勒心理困扰量表（K10）	参考文献 [46]
		积极和消极情绪量表（PANAS）中评估消极情绪的问题	参考文献 [56]
	心理障碍	欧洲生活质量五维问卷（EQ-5D）中评估抑郁和焦虑的问题	参考文献 [10]
		患者健康问卷（PHQ-9）	参考文献 [20]
		注意力缺陷多动障碍量表（ADHD）	参考文献 [42]
		重度抑郁量表（MDI）	参考文献 [43]
		军事版创伤后应激障碍检查表（PCL-M）	参考文献 [43]
		McKnight 风险因素调查（MRFS）	参考文献 [47]
		流行病研究中心抑郁量表（CES-D）	参考文献 [48]
		短版雷诺兹青少年抑郁量表（RADS-SF）	参考文献 [53]
		老年抑郁量表（GDS-15）	参考文献 [54]
		广泛性焦虑障碍量表（GAD-7）	参考文献 [56]
	其他	是否拜访心理医生或专家／被医生确诊焦虑症或抑郁症；是否服用相关药物／服用药物的频率	参考文献 [12][17][36][61]
		通过实验测度血压、心率等生理指标	参考文献 [52][59]
		因精神障碍住院的时间	参考文献 [21]

等方式暴露于城市蓝色空间，以观测其获得的心理健康效应。这类研究能够较好地控制暴露时长、方式等实验条件，从而更准确地评估蓝色空间心理健康的短期效应。此外，由于招募实验对象存在一定的难度，此类研究结论也会受到有限样本数量的影响。

4.2 城市蓝色空间特征对居民心理健康水平的影响

4.2.1 空间维度下城市蓝色空间特征对居民心理健康水平的影响

在纳入的文献中，基于空间维度的研究分别从邻近性、可获得性和可视性方面测度了城市蓝色空间特征与居民心理健康水平的关系，具体分析结果如下。

（1）邻近性

荟萃分析结果表明（表4），城市蓝色空间的邻近性与居民自我报告的一般心理健康（SMD=0.33，p=0.0001）、积极心理（SMD=0.15，p=0.006）呈显著正相关关系。具体来说，居住在接近城市蓝色空间的居民（如居住在离海岸线/河流附近）通常具有更好的自评心理健康状况[57]，这种效应在低收入群体中尤其明显[10]，并且随着居住时间的增加而加强[18]。研究还发现，户外活动（如海边散步）[35]与人居环境的感知恢复性质量[49]是城市蓝色空间影响心理健康的可能途径。例如，一项在比利时进行的研究表明，疫情封锁期间，沿海居民感受到的幸福感比内陆居民更高[63]。

然而，关于城市蓝色空间的邻近性对消极情绪影响的研究结果存在差异性。荟萃分析结果表明，城市蓝色空间的邻近性对消极心理的影响并不显著（SMD=–0.33，p=0.13），尤其是对于少年儿童群体而言[40][53]。这可能是因为消极心理的影响因素复杂多样，单一的蓝色空间暴露虽然有助于缓解焦虑和压力，但个体仍可能被其他因素所干扰，特别是在治疗抑郁症等心理障碍方面效果有限。其次，不同年龄层次的个体对城市蓝色空间的态度和使用模式存在差异，成年人可能更需要自然景观带来的情感慰藉和心理恢复，这加强了城市蓝色空间对他们心理健康的积极效应[40]。最后，地理环境的差异也会影响暴露效果，如一项在英国进行的研究表明，与海岸的邻近性对居民心理健康水平有积极效应[18]，而在面积较小的海岛国家[53]或地广人稀的加拿大[40]，邻近性的影响并不显著。

（2）可获得性

城市蓝色空间可获得性对居民的一般心理健康（SMD=0.16，p＜0.0001）和积极心理（SMD=0.91，p＜0.0001）显著正相关（表5）。换言之，居住地周围有蓝色空间或蓝色空间较多的城市居民具有更高的自评心理健康水平和更强的幸福感。研究表明，城市蓝色空间可获得性通过提升环境感知、体力活动及社交活动来增进居民心理健康水平[49][58]，且其效应可能超过了绿色空间[45]。此外，研究也发现童年居住环境可能对成年时的心理健康产生影响。一项在丹麦进行的研究发现，童年居住地周边1km内蓝色空间面积占比越高的居民，成年后越易于感到平静；虽然其与心理健康水平的关系未通过统计学检验，但回归系数为正[62]。类似积极的结论也曾在中国[14][60]、英格兰[10]、保加利亚[50]等地得到验证。一些研究通过居民的时空行为考量居住地和出行路径周围城市蓝色空间的影响。例如，中国的一项研究发现，日常出行路径周围（≤200m）的城市蓝色空间对个体心理健康水平的影响更为显著[14]，而在荷兰的研究则未发现居住地和出行路径周围城市蓝色空间的健康效应存在显著差异[20]。总体来看，城市蓝色空间可获得性被证实对心理健康

表 4：城市蓝色空间的邻近性与居民心理健康的效应量定量合成结果（n=11）

		SMD（95%CI）	异质性检验			统计检验		文献来源
			I^2	Chi^2	Df	z	p	
一般心理健康		0.33[0.16, 0.50]	81%	10.44	2	3.82	0.0001	参考文献 [10][18][35]
积极心理	主观幸福感	0.15[–0.07, 0.36]	98%	141.34	3	1.35	0.18	参考文献 [32][40][53][63]
	生活满意度	0.19[0.13, 0.26]	0%	0.73	1	5.79	＜ 0.00001	参考文献 [13][18]
	总和	0.15[–0.01, 0.30]	97%	41.06	4	2.73	0.006	—
消极心理	抑郁	–0.31[–0.75, 0.14]	91%	32.89	3	1.00	0.29	参考文献 [10][17][48][60]
	焦虑	–0.44[–0.91, 0.03]	—	—	—	1.83	0.07	参考文献 [17]
	总和	–0.33[–0.72, 0.06]	89%	37.91	4	1.67	0.13	—

表 5：城市蓝色空间可获得性与居民心理健康的效应量定量合成结果（*n*=13）

		SMD（95%CI）	异质性检验			统计检验		文献来源
			I^2	Chi^2	*Df*	*z*	*p*	
一般心理健康		0.16[0.08, 0.24]	100%	1 106.70	5	4.04	<0.0001	参考文献 [10][18][35][45][49][62]
积极心理	主观幸福感	1.02[0.26, 1.79]	72%	7.15	2	2.62	0.009	参考文献 [53][60][61]
	生活满意度	0.87[0.48, 1.26]	—	—	—	4.38	<0.0001	参考文献 [60]
	总和	0.91[0.47, 1.35]	58%	7.21	3	4.06	<0.0001	—
消极心理	抑郁	–0.33[–0.72, 0.06]	99%	422.21	6	2.52	0.01	参考文献 [10][12][20][21][36][60][61]

有益，但具体影响可能因地理位置和个体行为差异而异。

此外，城市蓝色空间可获得性对抑郁等心理障碍影响的荟萃分析结果显著（*SMD*=–0.33，*p*=0.01），且各项研究结果存在差异。虽然一些研究在特定情况下发现了城市蓝色空间的积极效应——例如，一项在苏格兰进行的针对老年人的研究发现，在淡水覆盖率高的社区，居民使用抗抑郁药的频率较低[12]；在中国的一项研究发现，居住地300m缓冲区内存在蓝色空间的情况下，居民抑郁症状占比显著较低[60]——但大多数研究未发现显著效应，例如，针对美国[47]和新西兰[53]的少年儿童、荷兰[20]和西班牙[36]的成年人，以及西班牙的阿尔茨海默病患者及家人[17]的研究均表明，城市蓝色空间可获得性与抑郁或精神障碍之间未见显著相关性。这些发现表明，虽然城市蓝色空间对某些群体可能具有益处，但对于预防或减轻心理障碍的效果可能比较有限，需要更多研究来探讨其影响机制和条件。

（3）可视性

受数据可获取性限制，仅四项研究探讨了城市蓝色空间可视性与居民心理健康水平之间的关联。受效应指标转换可行性的限制，无法进行荟萃分析。四项研究结果均表明，城市蓝色空间可视性不仅有助于居民自评心理健康，对消极心理亦有显著积极效应。丹尼尔·纽茨福特是最早关注城市蓝色空间可视性的健康效应的学者之一，其在新西兰进行的研究发现，在控制城市蓝色空间邻近性（如距离）等其他因素的情况下，能够看见海景的居民心理压力更小[46]。相似的结论也在爱尔兰的研究中被验证，学者发现住所海景能见度高的居民患抑郁症的风险更低，且就效应程度而言，可视性比邻近性效应更加显著[48]。近年来，中国学者亦基于街景图像就北京[54]和广州[15]蓝色空间可视性对居民心理健康水平的影响效应展开分析，发现较高的街景蓝色空间面积占比可以降低老年人抑郁风险，提高居民心理健康水平。

4.2.2 个体维度下城市蓝色空间特征对居民心理健康水平的影响

在所选文献中，基于个体维度的研究主要从个体行为特征（访问频率、访问蓝色空间的类型、访问距离等）及暴露方式两方面探讨了城市蓝色空间特征与居民心理健康水平的关联。这类研究的测度方法较为多样，不适宜进行荟萃分析，故本文采用文献定性描述的方式进行讨论。

（1）个体行为特征

学者们发现，经常访问（每周不少于1次）城市蓝色空间的群体通常具有较高的自评幸福感[13][32]，以及较低的心理困扰[61]和注意力缺陷[42]等消极心理状态；在儿童时期更多地访问城市蓝色空间对其成年后的心理健康状态亦有积极影响[65]。访问不同类型的城市蓝色空间也会导致差异化的心理健康效应。例如，在英格兰进行的研究发现，频繁访问（每月高于2次）河流、运河和海洋与更好的心理健康水平之间存在正相关，而频繁访问湖泊与之相关性则不明显[68]。这可能是由于不同类型的城市蓝色空间可提供的空间体验和体力活动有所差异，从而影响居民的心理健康水平。除访问频率外，居民到访城市蓝色空间与否[55]、蓝色空间可见与否[44]、疫情期间访问蓝色空间的可能性[63]、休闲路径上的蓝色空间环境特征[64]等均是影响居民心理健康的重要因素。此外，值得说明的是，虽然滨海、滨湖等城市蓝色空间环境对居民心理健康的恢复效益显著[39][41]，但其与抑郁症、压力等消极心理的关联同样存在争议[20][66]，尤其是在城市蓝色空间较少的地区，绿色空间对消极心理也发挥了重要作用[51]。

相较于截面分析等观察性研究，实验性研究多评估居民在城市蓝色空间中的体力活动（如散步[59]、冲浪[43]等）对心理健康的益处。这类研究通过比较活动前后的生理指标变化（如脉搏、血压等），揭示了在城市蓝色空间内进行体力活动可提高恢复性体验[34]和感知[64]，并有效改善心理状态[33][52]。例如，在西班牙进行的研究发现，在城市蓝色空间中散步的实验分组成员，活动后幸福感和情绪反应均有显著提升[59]。这种积

极效应不仅限于一般人群，也被证实可作用于严重心理障碍患者，如创伤后应激障碍症（PTSD）患者参与冲浪活动后症状有显著缓解[43]。类似发现也在西班牙[33]、美国[34]和英国[56]的研究中得到了验证。同样地，实验性研究亦发现不同类型的城市蓝色空间对居民的恢复效应有差异，如海滩比堤坝和港口的恢复能力高约30%[69]。

（2）暴露方式

只有少量研究评估了城市蓝色空间暴露方式对居民心理健康水平的影响效应。例如，中国香港的一项研究发现，访问蓝色空间的故意暴露与居民的幸福感正相关，而从家中看到蓝色空间的间接暴露与居民自我感知身体健康水平正相关，但与心理健康并无显著关联[32]。在中国广州进行的研究发现，相较于间接暴露，出行带来的偶然暴露对居民心理健康效益更加显著[14]。此外，短期城市蓝色空间的故意暴露对心理健康有积极影响。在英国开展的研究显示，近期特意访问过河道、运河等城市蓝色空间的居民，生活满意度和心理健康水平更高[38][67]。另一项在西班牙的研究则比较了对城市公园与海滩等蓝色空间的目的性访问对心理恢复的效果，发现蓝色空间访问者报告了更高的放松和注意力恢复水平[11]。这些发现表明，城市蓝色空间的不同暴露方式对居民心理健康水平呈现出不同的影响。

5 结论与讨论

本文聚焦城市蓝色空间特征对居民心理健康的影响，对相关研究的指标测度、研究模型和心理健康效应进行了系统审查和荟萃分析。研究发现：1）在指标测度方面，城市蓝色空间特征测度可分为基于空间维度（居住地或工作地）的测度——邻近性、可获得性、可视性——和基于个体维度（个体访问特征、暴露方式）的测度。2）探讨的心理健康类型主要包括一般心理健康、积极心理（主观福祉、恢复性感知和积极情绪）和消极心理（消极情绪和心理障碍）三个方面。3）在心理健康效应方面，城市蓝色空间特征对居民心理健康的影响在不同研究中表现出较大差异，尤其是对抑郁、应激障碍等心理障碍的影响方面存在争议。具体而言，城市蓝色空间的邻近性在提升居民的一般心理健康和积极心理方面具有显著的积极影响；城市蓝色空间的可获得性与一般心理健康和积极心理呈显著正相关；可视性、访问频率和暴露方式等因素虽对心理健康有影响，但相关研究的数量仍较为有限，未来有必要进一步探索。

现有关于自然环境与健康的研究多聚焦于绿色空间，本文的研究结果表明蓝色空间对于居民的心理健康同样具有价值。本研究采用荟萃分析测度城市蓝色空间特征对一般心理健康和积极心理的效应量，以量化结果支持了蓝色空间可以对心理健康产生积极影响的观点。在绿色空间的心理健康效应方面，有研究发现，接触绿色空间能够有效缓解焦虑、抑郁等消极心理[23]。本文的研究结果显示，城市蓝色空间邻近性对于缓解居民焦虑的效应量与绿色空间相似，而邻近性和可获得性对抑郁、焦虑的影响存在争议。蓝色空间是大部分城市的重要组成部分——城市居民距淡水的中位距离仅为3.1km[7]——因而剖析城市蓝色空间的健康效应、利用其健康促进能力对健康城市建设意义重大。

虽然现有研究已取得了较为丰富的成果，在未来的研究中仍需重点关注以下方面。

1）增加发展中国家及内陆城市的实证研究：不同地理背景下城市蓝色空间的健康效益存在显著差异。现有研究多集中于欧美发达国家，而针对发展中国家的相关研究占比较少——少量关于中国的实证研究也聚焦于广州、香港等沿海城市，对于内陆城市的关注尤为不足。今后有待对更多城市，尤其是发展中国家及内陆城市展开实证研究，进一步探究城市蓝色空间的心理健康效益。

2）探索精细化城市蓝色空间及居民心理健康指标测度：现有城市蓝色空间特征的测度多基于大尺度的土地利用数据或遥感影像数据，相应研究忽视了大量小尺度的城市蓝色空间对居民心理健康的影响。而池塘、湖泊等小型水体是全球数量最多的水体环境，对淡水生物多样性至关重要，并在生态系统服务中发挥着重要作用[75]。此外，现有研究中关于居民心理健康的分析多采用量表数据，未来有待开展更多关于心率、血压等心理健康生理数据的实验性研究，并对指标测度方法和体系进行精细化探索。

3）拓展城市蓝色空间特征对居民心理健康影响的研究内容：其一，现有研究多以海洋或内陆蓝色空间为单一研究对象，仅有少量研究对比了二者对心理健康的不同影响。未来可对不同内陆城市蓝色空间类型进行划分（如江河、湖泊、坑塘等），以进一步探讨它们健康效应的差异。其二，相关研究多探讨城市蓝色空间邻近性、可获得性等数量指标对居民心理健康的影响，未来研究可加强探究蓝色空间质量因素的影响。其三，对城市蓝色空间特征的指标评估多基于单一的空间维度或个体维度开展，未来研究可基于居民出行数据将两个维度结合起来，综合分析蓝色空间特征对心理健康影响的效应差异。

4）深化中介效应机制的探讨。现有研究对城市蓝色空间影响居民心理健康的中介机制的探讨较少，尤其是蓝色空间独有的效应机制。未来研究应积极探讨声环境、体育活动、社会交往等中介因素的效应机制。

图 1. 城市蓝色空间对居民心理健康影响的理论框架
图 2. 文献检索、筛查与排除流程
图 3. 文献分布统计图（3-1. 年份分布；3-2. 研究对象分布；3-3. 地理分布）