The effect of urban nature exposure on mental health-a case study of Guangzhou

Liu, H.X.; Ren, H.; Remme, R.P.; Nong, H.F.; Sui, C.H.

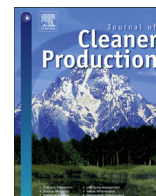# The effect of urban nature exposure on mental health—a case study of Guangzhou

Hongxiao Liu [a, b], Hai Ren [a], Roy P. Remme [c, d], Huifu Nong [e, f, *], Chunhua Sui [g]

[a] CAS Engineering Laboratory for Vegetation Ecosystem Restoration on Islands and Coastal Zones, South China Botanical Garden, Chinese Academy of Sciences, Guangzhou, 510650, China
[b] Southern Marine Science and Engineering Guangdong Laboratory (Guangzhou), Guangzhou, 511458, China
[c] Institute of Environmental Sciences CML, Leiden University, Einsteinweg 2, 2333, CC, Leiden, the Netherlands
[d] Natural Capital Project, Dept. of Biology and Woods Institute for the Environment, Stanford University, Stanford, CA, 94305, USA
[e] School of Finance and Investment, Guangdong University of Finance, Guangzhou, 510521, China
[f] Dept. of Economics, Sun Yat-sen University, Guangzhou, 510275, China
[g] Tourism Department of Shaoguan University, Shaoguan, 512005, China

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ABSTRACT

There is considerable evidence concerning the salutary effects of nature on mental health in developed countries. However, these benefits are less examined and recognized in Chinese cities where 11%–15% of the population are facing increasing mental health issues. To provide more comprehensive evidence concerning nature's benefits on multiple components of mental health in Chinese cities, we address two poorly resolved questions: i) does exposure to urban park and blue space have equivalent associations with multiple components of mental health? ii) do these associations vary across gender and socio-economic groups? We conducted two waves of cross-sectional surveys in Guangzhou and investigated 1,274 respondents' (933 from online survey and 341 from face-to-face survey) depression risk and four aspects of subjective well-being (SWB) including life satisfaction, worthwhileness, happy yesterday, and anxious yesterday. The results suggest that both park and blue space exposure mitigate depression risk and negative affect well-being, however their associations vary with evaluative, eudemonic, and positive affect well-being. Achieving SWB across all its components needs access to both park and blue space. One-hectare increase in accessible water is associated with an improvement up to 0.45% anxious yesterday scores indicating blue space a potential public health resource. We observed a clear gender- and socioeconomic differences: nearby nature has stronger protective effects for female, lower educated and low-to-median income population groups than their counterpart. Although the heterogeneities need to be confirmed in other urban settings, our findings suggest that effective actions need to consider gender- and socioeconomic differences to target potential beneficiaries and maximize the returns of investments and policy interventions.

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1. Introduction

The Report on National Mental Health Development in China (2017–2018) revealed that 11%–15% of the Chinese population have mild to moderate mental health conditions and 2%–3% have moderate to serious mental health conditions (Fu and Zhang, 2019).

A growing body of empirical evidence in developed countries has revealed the benefits of nature exposure to human mental health through mitigating environmental stressors such as air pollution and noise (Frumkin et al., 2017), restoring attention, reducing stress (Bratman et al., 2012), providing a pleasant venue for social interactions, and fostering physical activities (Hartig et al., 2014). However, there are only few empirical evidence available concerning Chinese cities (Liu et al., 2020). China's population grew to 1.4 billion in 2018, and 59% resided in urban settlements (United Nations, 2019). Clearly, empirical studies on Chinese cities, such as rapidly urbanized Guangzhou—the city under study—are needed to provide insights for effective interventions given the

notable differences in culture, economic development, life style, urban form, etc., between Chinese and western cities (Amano et al., 2018).

Mental health is a multi-dimensional measure and it encompasses the absence of common mental disorders and a complete state of subjective well-being (SWB; Keyes, 2006). Building on long-standing debates, there is growing research and policy consensus that there are four components of SWB: a) evaluative well-being, how well individuals think their life is going overall, b) eudaimonic well-being, how worthwhile individuals think their behaviors are, c) positive, and d) negative affect well-being, the emotions of pleasure (e.g., happiness) and pain (e.g., anxiety) individuals regularly experience (Kahneman et al., 1999; O'Donnell et al., 2014; White et al., 2017). To date, evidence concerning nature and mental health remains fragmented as most studies focused either on specific mental illness or a specific aspect of SWB. For example, Callaghan et al. (2020)'s review found only 8 out of 25 studies measured two or more mental health aspects, among which four studies measured more than one mental illness, while neglecting SWB dimensions. The other four measured more than one dimension of SWB, but overlooking the mental illness dimension. A comprehensive and precise understanding of nature's impacts on multiple aspects of mental health is lacking. However, this is important for policymakers since, for example, the benefit of promoting positive mental health is different from reducing mental illness (Gascon et al., 2015).

In this study, we simultaneously measured MHI-5 (Mental Health Inventory), a marker of psychological ill-health (Thorsen et al., 2013) and four aspects of SWB including evaluative (life satisfaction), eudaimonic (worthwhileness), negative and positive affect well-being (happy yesterday and anxious yesterday) to provide comprehensive evidence on nature's association with multiple components of mental health in Guangzhou, China.

Urban greenspace includes parks, street trees, residential greenspace, vegetated sports field, urban forest etc. Overall greenness measured by Normalized Difference Vegetation Index (NDVI) and public greenspaces are most studied (Callaghan et al., 2020). Urban parks, which often consist of vegetated areas, are drawing increasing attention due to their strong implications for public policy (Wood et al., 2017). Cumulative opportunity measures (amount/number of parks within certain spatial area) or proximity measures (the access to nearest park) are often measured as exposure metrics (Ekkel and de Vries, 2017; Wood et al., 2017). One element that is rarely studied is the size of parks. Large parks are reported to associate with higher physical activity, one pathway that mediates the association between nature and mental health (Zhang et al., 2019). However, park size is often addressed by setting a minimum area threshold when calculating proximity indicators in previous research (e.g., analyzing the effect of parks larger than 1 ha on mental health) (Ekkel and de Vries, 2017). Whether park size matters in improving mental health requires further exploration, as the answer has consequences for spatial planning. For example, would it be more advantageous for mental health to build one big park or rather two smaller parks that are accessible to more people?

Compared with greenspace, the salutary effects of blue space are less studied, with mixed results, and most are conducted in coastal cities (Gascon et al., 2017). Blue space is hypothesized to support mental health through similar pathways proposed for greenspace (Gascon et al., 2017). However, the effects of blue space are confirmed by very few studies in Chinese cities and most are conducted in older adults (Chen and Yuan, 2020; Garret et al., 2019; Helbich et al., 2019). It is still unknown how blue space will associate with both mental illness and SWB in the general urban Chinese population.

The heterogeneity in associations between nature exposure and mental health among population subgroups mandates further research (Gascon et al., 2015, 2018; Ruijsbroek et al., 2017). Several studies included stratified analysis according to socio-demographic factors (e.g., gender, life stage, ethnicity, socioeconomic status, etc.) and reported mixed findings (further elaborated in Section 2). Empirical evidence has not clarified whether exposure to nature benefits certain population subgroups more than others because of inconsistent evidence across studies (Gascon et al., 2015, 2018). However, accounting for the heterogeneity in subgroup populations is important to target potential beneficiaries and maximize the returns of policy interventions. To our knowledge, these varied associations are not explored in Chinese cities yet, although some studies focus on certain population groups such as older adults (Helbich et al., 2019) and college student (Yang et al., 2019).

To address the aforementioned questions, we conducted a cross-sectional study in Guangzhou. Previous studies have examined the relationships between NDVI, street greenery and mental health in Guangzhou, which provided useful insights (Liu et al., 2019, 2020; Wang et al., 2019, 2020). However, the effects of parks and blue space on multiple mental health components, and their heterogeneity in subgroup populations remain unassessed. We attempt to answer the following questions: i) does exposure to urban parks and blue space have equivalent associations with multiple components of mental health? ii) do these associations vary across gender and socioeconomic groups?

2. Literature review

Multiple reviews synthesizing progress on the association between nature and mental health have been published in the last decade (Callaghan et al., 2020; Douglus et al., 2017; Gascon et al., 2015, 2017; Houlden et al., 2019; Shuvo et al., 2020; WHO, 2016). We compiled 98 studies from five recent reviews and additional 8 studies in Chinese cities and analyzed the mental health outcomes, population subgroups studied, green/blue space exposure and the main results (Table A.1 in Appendix). A wide spectrum of mental health outcomes were assessed, among which about 30% of studies assessed specific mental illness including depression (Cohen-Cline et al., 2015), behavioral problems (Markevych et al., 2014), anxiety (Shuvo et al., 2020), mental disorder symptoms (Nutsford et al., 2013), or risk factor of mental illness (Bratman et al., 2015). Mental illness is assessed by validated tools such as K10 (Kessler Psychological Distress), self-reported symptoms (de Vries et al., 2003), or prescription records (Nutsford et al., 2013). About 30% of studies assessed general mental health, mostly using GHQ (General Health Questionnaire) or a single item question on perceived general mental health. Scarce studies used valid measurement comprising all-round SWB. WEMWBS (Warwick-Edinburgh Mental Well-being Scale), WHO-5 (WHO well-being index), and PANAS (Positive and Negative Affect Scale) are commonly used SWB assessment tools, among which WEMWBS includes hedonic and eudaimonic well-being, WHO-5 focuses on hedonic well-being and PANAS focuses on affect well-being. A four-item subjective well-being tool (ONS4) suggested by the Office for National Statistics of UK includes four dimensions of SWB and was used in three studies (Houlden et al., 2009; White et al., 2013a, 2017). However, the majority of studies measured one aspect of SWB such as life satisfaction, happiness, or quality of life (Kamitsis and Francis, 2013; White et al., 2013b). Less than half of studies assessed two or more mental health components, most of which focus either on multiple mental illnesses, or some dimensions of SWB. There is no single study that investigated mental illness and comprehensive SWB. Due to the variety of mental health and exposure measurements used, it is impossible to further synthesize these results.

Therefore, a comprehensive and precise understanding on the associations between nature and multiple dimensions of mental health is still lacking.

Although studies have shown mental health benefits from nature in a variety of populations, many studies also showed divergent associations dependent on demographic factors, including gender, age, ethnicity, and socioeconomic status (WHO, 2016). Multiple studies found that females are more likely to benefit from nature than males. Bjork et al. (2008), Reklaitiene et al. (2014) and (Van den Bosch et al. 2015) only found beneficial effects for women. McEachan et al. (2016) found protective effects of nature on depression in pregnant women, especially in the disadvantaged population. However, there are also notable exceptions with opposite findings that beneficial effects are stronger for men (Markevych et al., 2014; Triguero-Maset et al., 2017).

Multiple studies found that individuals from lower socioeconomic positions are more inclined to benefit from nearby greenspace, alleviating the adverse effects of poverty and reducing health disparities—the so-called "equigenic" effect (Frumkin et al., 2017; Mitchell and Popham 2007, 2008; Mitchell et al., 2015). However, a review on low-middle income countries suggested that socioeconomically advantaged communities benefited more from urban greenspace probably modified by better access to greenspace and physical activity (Shuvo et al., 2020). Literature generally endorses the view that urban greenspace promotes mental health across the life course (Douglas et al., 2017). Gascon et al. (2015) concluded that there is some, yet limited, evidence for a positive relationship between greenness and mental health in adults, whereas the evidence was inadequate in children. In addition, ethnicity (McEachan et al., 2018), urbanization level (de Vries et al., 2003), and population density (Ambrey, 2016) are found to modify the association between nature exposure and mental health.

Research on the mental health benefits of nature is a recent interest in China (Liu et al., 2017a; Wang et al., 2020). Most studies on Chinese cities explored the effects of nearby greenspace using cumulative opportunity measures such as NDVI, street view, greenspace within 1 or 1.5 km buffer. Residential greenness is found to improve mental health through physical activities and social interaction (Liu et al., 2019), while street greenery benefits mental health by additional pathways including reduced air pollution, noise reduction, and stress relief (Wang et al., 2019). The effects of blue space on mental health are rarely assessed and most are conducted among older adults. One study investigated the association between general mental health and blue space area within a 1.5 km buffer without considering SWB (Liu et al., 2020). Most studies concerning Chinese cities consistently support positive associations between nature exposure and mental health, however, the evidence base is small and additional research remains critical given the narrow range of nature exposure and mental health components examined. Green/blue space proximity and size are rarely considered and limited mental health components are assessed, generally, either a general mental health metric (mostly GHQ-12) or hedonic well-being (mostly WHO-5) are applied (Garrett et al., 2019; Liu et al., 2020). We found no studies investigating the diversity of nature's benefits on mental health in multiple population subgroups, which is another gap that requires further research.

3. Material and methods

3.1. Survey design

We conducted a mixed mode cross-sectional survey in Guangzhou which combines online and face-to-face surveys to reduce noncoverage and nonresponse error. The online survey was conducted in July and August in 2018 by Wenjuanxing, a survey company that has experience investigating mental health of the Chinese population (https://www.wjx.cn/, Li et al., 2020). We followed the key steps for conducting valid and meaningful online survey as identified by Regmi et al. (2016): (1) user-friendly design and layout; (2) selecting survey participants; (3) avoiding multiple responses; and (4) a pilot study. For steps 1 and 4, we conducted a paper survey with 30 participants, including people of different ages and educational backgrounds, and invited them to comment on the readability of the questionnaire and ordering of the questions. We also did a pilot of 147 online samples to ensure the feasibility of the technology, data transfer, etc. Selecting survey participation (step 2) is important for collecting valid data. Everyday there are on average 1000,000 people responding to surveys, exams, and votes conducted on Wenjuanxing. Wejuanxing invites these people to provide demographic information (age, gender etc.) and join in their sample database. To make sure the participants are real and unduplicated, Wenjuanxing created an account for every member in their sample database which is tied to the phone number, Wechat, or Alipay of the member. Currently, it has a sample database of 2,600,000 people, comprising diverse occupations, age, wealth statuses, hobbies, etc., which constitutes the sample frame for a survey (for the structure of the sample database see https://www.wjx.cn/). Wenjuanxing randomly invites participants in the sample database to complete the survey for financial compensation. To avoid duplicated response due to the incentives (Step 3), the link of the questionnaire became invalid once a response was submitted. Three steps were applied to control the quality of the questionnaire: (1) We deleted questionnaires completed in less than 3 min (2) Trap questions (e.g., let the respondent choose the answer "Agree" in options such as "Disagree", "Strongly agree", "Neutral" etc.); were set to check the attention respondents were paying; (3) We manually excluded other invalid samples such as incomplete questionnaires and questionnaire that had logic contradictions. We collected 933 samples of which 62% were women and only 10% of the sample was over 40 years old.

We applied a face-to-face survey among men and elderly adults who were underrepresented in the online survey from August 20th to September 8th, 2020. We took a stratified sampling technique and selected 23 residential communities (xiaoqu) according to house price and neighborhood greenness. We checked 6,654 residential community information (house price, location etc.) from *fangtianxia*, a leading online real estate portal in China. A residential community with higher than average house prices was defined as "high price" and a residential community with below-average house prices was defined as "low price". We calculated the NDVI in a 500m buffer around each residential community to represent the neighborhood greenness level. A residential community with higher NDVI than the average is defined as "high greenness" and a residential community with lower NDVI than the average is defined as "low greenness". Finally, we selected 23 residential communities according to house price and neighborhood greenness level: 6 in the low price and low greenness category (referred to as low-low), 5 with low house prices and high greenness (low-high), 7 of high-low, and 5 of high-high (Table A2 in Appendix). Respondents in these communities were randomly invited to complete the questionnaire with a 2–3 US $ worth of gift. To reduce measurement errors associated with two different survey modes the questionnaires used in the online and face-to-face surveys were identical.

3.2. Depression risk and SWB outcomes

We employed the widely used Mental Health Inventory (MHI-5), to investigate the population's depressive symptoms (Cuijpers

et al., 2009). MHI-5 asks the frequency of five situations in the past month: (i) you have been a very nervous person, (ii) felt down-hearted and blue, (iii) felt calm and peaceful, (iv) felt so down in the dumps that nothing could cheer you up, and (v) been a happy person. The questions could be answered on a 6-point Likert scale: from 1 (*all of the time*) to 6 (*none of the time*). The scoring of positive feelings—items (iii) and (v)—was inversed and summed with the scores from other questions. The mean score of the five items are transformed into a 100-point scale.

We followed the four-item construct used by the Office for National Statistics of the UK to evaluate SWB (Coldwell and Evans, 2018; White et al., 2017). Four components of well-being were measured: evaluative, eudemonic, positive, and negative affect well-being. For the evaluative well-being, we asked, "Overall, how satisfied are you with your life?" on a scale from 1 (*not satisfied at all*) to 10 (*very satisfied*). For eudemonic well-being, we asked, "Overall, to what extent do you feel that the things you do in your life are worthwhile?" on a scale from 1 (*not worthwhile at all*) to 10 (*very worthwhile*). For positive and negative affect well-being, we asked, "Overall, how happy did you feel yesterday?" on a scale from 1 (*not happy at all*) to 10 (*very happy*), and "Overall, how anxious did you feel yesterday?" on a scale from 1 (*not anxious at all*) to 10 (*very anxious*). Similar to the MHI-5 score, we inversed negative measures and converted scores into a 0−100 scale, with higher scores indicating better SWB.

3.3. Urban park and blue space exposure

Park exposure is measured by the nearest park area and road network distance to the nearest park. Urban park data were obtained from the Bureau of Forestry and Landscaping of Guangzhou Municipality (http://lyylj.gz.gov.cn/). 211 parks were included. Road network data were obtained from Open Street Map (https://download.geofabrik.de/). For the online survey, residents' home locations were obtained by asking respondents to point their residence on an interactive map. For the face-to-face survey, the locations of the residential communities are identified in Gaode map (https://www.amap.com/). Then, residents' home locations, the park layer, and the road layer were analyzed in Network Analysis tool in ArcGIS to identify the network distance to the nearest park.

Blue space includes reservoirs, rivers, water, and wetlands. Spatial information was obtained from the Open Street Map (https://download.geofabrik.de/). In line with prior literature (Dzhambov et al., 2018), we calculated the water area within 300m, 500m, and 1000m buffers from residents' homes. We measured the Euclidian distance from respondents' homes to the nearest water body.

3.4. Demographic and socioeconomic covariates

We recorded participants' gender, age, education, income, occupation, marital status, and residence location which have been identified in the literature as confounders impacting the association between nature and mental health (Gascon et al., 2018). In Guangzhou, five districts—Liwan, Yuexiu, Haizhu, Tianhe, and Baiyun—are considered as central urban areas, while the rest are considered as peripheral urban areas. They differ in population density, economic development, and urbanization level. We generated a variable (residence location) representing if respondents lived in central or peripheral areas. Since mental health is impacted by life events (van den Berg et al., 2010), we further included one item in the survey to assess recent life events in the survey by asking, "Have you lately experienced a stressful life event, such as death/illness of family, lost job, sickness, breaking of an intimate relationship, etc.?"

3.5. Statistics

A mixed mode survey has the advantage of reducing the total survey error at an affordable cost. However, a combination of different survey modes in one study may lead to different errors due to mode effects. The mode effects include two major components. The first component is mode (self) selection effects, i.e., some population may prefer certain survey type, thus, different modes are associated with different noncoverage and nonresponse errors. Following de Leeuw et al., 2018, we controlled all possible demographic variables (gender, age, education, occupation, income, district of residence, marriage status) to adjust mode selection effects. The second component is mode measurement effects, i.e., different modes produce different observation errors. We added a dummy variable indicating survey mode to adjust measurement error.

Quadratic and cubic terms were tested for a potential nonlinear relationship between the park and blue space exposure and mental health outcomes. Since no significant association were observed, we applied linear regression analysis. We constructed regressions for parks and blue space separately. For blue space, we analyzed 300m, 500m, and 1000m buffers separately. The model for parks and blue space are specified as:

$Mental\ health = \beta_0 + \beta_1 Dummy_{wave} + \beta_2 NearParkArea + \beta_3 NetworkDis + \beta_4\ confounders$ (Eq. 1 for park)

$Mental\ health = \beta_0 + \beta_1 Dummy_{wave} + \beta_2 WaterArea_i + \beta_3 NearWaterDis + \beta_4\ confounders$ (Eq. 2 for blue space)

Where *mental health* is MHI-5, life satisfaction, worthwhileness, happy yesterday and anxious yesterday score, respectively. β_0 is the intercept. β_1, β_2, β_3, and β_4 are the coefficients. $Dummy_{wave}$ is 0 for the online survey, and 1 for the face-to-face survey. *NearParkArea* is the area of the nearest park (unit: ha). *NetworkDis* is the network distance to the nearest park (unit: meter). Cofounders include gender, age, occupation, education, income, residence location, marital status, life event. $WaterArea_i$ is the water area within a certain buffer of residence (i = 300m, 500m, 1000m). *NearWaterDis* is Euclidean distance to the nearest water.

To examine the heterogeneous relationship between nature exposure and mental health, we stratified the sample according to gender, income, and education—which were previously identified as modifiers (Gascon et al., 2015).

As for the robustness check, we randomly excluded 10% of sample and then conducted a regression with the remaining 90% sample, controlling all confounders. We repeated this process 500 times and plotted the coefficients of the independent variable subjected to the robustness check for each regression. The full sample regression result is robust if it does not deviate from the results of the 500 regressions with 90% of sample. All statistical analyses were conducted in Stata 14.

4. Results

4.1. Descriptive statistics

We collected 1,274 valid questionnaires, with 933 responses in the online survey and 341 responses in the face-to-face survey. Women accounted for 55% of the sample. People under 20, between 20 and 60, and over 60 accounted for 17%, 75%, and 8% respectively (Table 1). Respondents with high school or below, junior college, college, or a graduate education accounted for 30%, 20%, 45%, and 4% of the population, respectively. Enterprise staff, governmental

staff, and self-employed accounted for 35%, 10%, and 7% of the sample. About two-thirds (62%) were married. Two-thirds (70%) lived in the central area. Half (49%) earned less than $750 per month, 34% had a monthly income between $750−1,500, and 17% earned more than $1,500 per month. The mean (±standard deviation) MHI-5 score of the sample was 63 ± 14. The highest SWB component was the "worthwhileness" score (74 ± 19) and the lowest was the "anxious yesterday" score (59 ± 25).

4.2. Full-sample regression

The nearest park area was significantly associated with MHI-5 (p = 0.002), "worthwhileness" (p = 0.069), "happy yesterday" (p = 0.075), and "anxious yesterday" scores (p = 0.052) after controlling all confounders (Table 2). Road network distance to the nearest park was not associated with any mental health outcomes.

A water area within 300m from respondents' homes was positively associated with MHI-5 (p = 0.003), life satisfaction (p = 0.079), and "anxious yesterday" score (p = 0.09, Table 2). The water body within 500m and 1000m buffers were not significantly associated with any mental health outcomes. However, associations between distance to the nearest water and "happy yesterday" and "anxious yesterday" were observed (Table 2, Table A.3 in Appendix).

4.3. Stratified sample regression

Stratified regressions by gender showed that access to large parks was positively associated with all SWB indicators among women; Both men and women benefitted from a nearby park in the reduction of depression risk. However, the effects are more significant in women (p = 0.022 for women, and 0.046 for men) and men marginally benefit from access to a nearby park in reducing the "anxious yesterday" score (p = 0.09, Table 3). Protective effects on mental health from a nearby blue space were observed only in women (Table 3).

Stratified by income, only in the median-income population was there a significant association between the nearest park area and MHI-5 and "happy yesterday" score (Table 4). Shorter distance to the nearest park also contributed to better MHI-5 scores in the median-income population. Significant improvements in MHI-5, life satisfaction, and "anxious yesterday" scores were found in low-income populations who had access to water within a 300m buffer. No protective effect was observed in the high-income

groups regardless of whether they were near a larger park or water area (Table 4).

In both low- and high-educated populations, a nearby large park was associated with better MHI-5 scores. However, the nearest park area was associated with "happy yesterday" and "worthwhileness" score only among less-educated respondents. Blue space exposure was correlated with better MHI-5 and all SWB components only in less-educated respondents (Table 5).

4.4. Robustness checks

Since the full sample regression showed that the *nearest park area* and *water area within 300m buffer* are the strongest predictive variables, a robustness check was conducted on these two variables. The results of the robustness check (Fig A.1 in Appendix) are consistent with what is displayed in Table 2. For instance, as shown in the upper-left panel in Fig A.1, most subsample regression coefficients of the *nearest park area* with MHI-5 were significant (p < 0.05), which is consistent with the first column in Table 2.

5. Discussion

Our research provides evidence for positive associations between nature exposure and lowers depression risk as well as higher SWB. However, nature contributes distinctly to different aspects of mental health. Both park and blue space exposure had a stronger correlation with lower depression risk (MHI-5) compared with their associations with SWB. Moreover, both park and blue space exposure have significant mitigation effects on short-term negative affect well-being ("anxious yesterday"). However, their associations vary among other SWB components. People who experience negative feelings may unconsciously choose to expose themselves to a restorative environment so that the protective effects are more prominent in mitigating negative emotions. For example, Hartig and Staats (2006) found that mentally fatigued people are inclined to walk in a natural environment rather than in urban settings. Park and blue space exposure associated with different components of SWB. However, achieving improved SWB across all its components requires access to both green and blue space.

Park size (area of the nearest park) is a predictive variable of mental health instead of proximity measures, highlighting the benefits of a larger park. Larger parks often have more facilities and amenities that promote visitation and physical activity, which may generate positive mental health outcomes (Wang et al., 2019).

Table 1
Summary statistics of sampled respondents (n = 1274).

Variables	Level	Percent	Variables	Level	Percent/Mean ± SD
Gender	Female	55%	Education	High school or below	30%
	Male	45%		Junior college	20%
Age	under 20	17%		College	45%
	20−30	38%		Graduate	4%
	30−40	18%	Marital status	Single	38%
	40−50	12%		Married	62%
	50−60	7%	District	Inner city	70%
	over 60	8%		Peripheral city	30%
Employment	Enterprise staff	35%	Monthly income	Less than750$	49%
	Governmental institution	10%		750-1500	34%
				Over 500$	17%
	Self-employed	7%	MHI-5 score		63 ± 14
	Freelancers	12%	Life satisfaction		72 ± 19
	Student	21%	Worthwhileness		74 ± 19
	Retiree	11%	Happy yesterday		73 ± 22
	unemployed	1%	Anxious yesterday		59 ± 25
	Other	3%			

Online survey: 933 samples; face-to-face survey: 341 samples.

Table 2
Associations between the park and blue space exposure and MHI-5 and subjective well-being (n = 1274).

Variables	MHI-5	Life satisfaction satisfaction	Worthwhileness	Happy yesterday	Anxious yesterday
NearParkArea	**0.003*****	0.002	**0.003***	**0.003***	**0.004***
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)
NetworkDis	−0.000	0.000	−0.000	−0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R²	0.136	0.179	0.153	0.168	0.203
WaterArea300m	**0.325****	**0.348***	0.268	0.374	**0.446***
	(0.149)	(0.198)	(0.206)	(0.229)	(0.265)
NearWaterDis	0.000	0.000	0.000	−0.002	**−0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R²	0.133	0.180	0.152	0.170	0.206

Note: Standard errors in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1; NearParkArea: Area of the nearest park; NetworkDis: Road network distance to the nearest park; WaterArea300m: Water body area within 300m buffer from respondent' home; NearWaterDis: Euclidean distance to the nearest water body; All regression controlled gender, age, education, occupation, income, marital status, residence location, life event, and mode of survey.

Table 3
Stratified associations between park/blue space exposure and MHI-5 and subjective well-being by gender.

Variables	MHI-5		Life satisfaction		Worthwhileness		Happy yesterday		Anxious yesterday	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
NearParkArea	**0.003****	**0.003****	**0.004****	−0.001	**0.004****	0.001	**0.004***	0.001	**0.006****	0.000
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.003)
NetworkDis	0.000	**−0.001***	0.000	0.000	−0.000	0.000	−0.000	−0.000	0.000	**−0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.000)	(0.001)
R²	0.174	0.129	0.192	0.192	0.184	0.135	0.219	0.151	0.239	0.208
WaterArea300m	**0.486****	0.203	**0.641****	0.076	**0.802*****	−0.214	**0.786****	−0.096	0.464	0.391
	(0.215)	(0.209)	(0.276)	(0.291)	(0.292)	(0.295)	(0.327)	(0.321)	(0.371)	(0.384)
NearWaterDis	0.000	0.000	0.001	−0.000	0.001	−0.001	−0.001	−0.003	−0.003	−0.002
	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
R²	0.174	0.122	0.192	0.192	0.188	0.136	0.224	0.154	0.238	0.207
Observations	710	564	710	566	710	566	710	566	710	566

Note: Standard errors in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1; NearParkArea: Area of the nearest park; NetworkDis: Road network distance to the nearest park; WaterArea300m: Water body area within 300m buffer from respondent' home; NearWaterDis: Euclidean distance to the nearest water body. All models control for the mode of survey, age, education, occupation, income, marital status, residence location, and life event.

Table 4
Stratified associations between park/blue space exposure and MHI-5 and subjective well-being by income.

Variables	MHI-5			Life satisfaction			Worthwhileness			Happy yesterday			Anxious yesterday		
	Low	Median	High	Low	Median	High	Low	Median	High	Low	Median	High	Low	Median	High
NearParkArea	0.002	**0.005*****	0.003	0.002	−0.000	0.004	0.002	0.001	0.007	0.001	**0.005***	0.003	0.002	0.005	0.004
	(0.001)	(0.002)	(0.003)	(0.002)	(0.002)	(0.005)	(0.002)	(0.002)	(0.005)	(0.002)	(0.003)	(0.005)	(0.002)	(0.003)	(0.007)
NetworkDis	0.000	**−0.001****	−0.001	−0.000	0.000	−0.000	0.000	−0.000	−0.000	−0.000	0.000	−0.000	−0.000	−0.001	−0.001
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
R²	0.193	0.143	0.131	0.176	0.148	0.259	0.150	0.127	0.207	0.202	0.133	0.202	0.277	0.183	0.187
WaterArea300m	**0.452****	0.350	−0.482	**0.448***	0.106	0.222	0.249	0.117	0.382	0.460	0.198	0.636	**0.687****	−0.256	0.968
	(0.196)	(0.265)	(0.504)	(0.264)	(0.353)	(0.671)	(0.275)	(0.365)	(0.688)	(0.303)	(0.400)	(0.808)	(0.333)	(0.480)	(0.969)
NearWaterDis	−0.000	0.001	−0.001	−0.000	−0.000	0.001	0.000	−0.000	−0.001	−0.002	−0.001	−0.003	−0.002	−0.004	−0.006
	(0.001)	(0.001)	(0.003)	(0.001)	(0.002)	(0.004)	(0.002)	(0.002)	(0.004)	(0.002)	(0.002)	(0.004)	(0.002)	(0.003)	(0.005)
R²	0.199	0.124	0.129	0.178	0.148	0.255	0.150	0.127	0.200	0.210	0.127	0.208	0.287	0.179	0.201
Observations	628	433	213	629	434	213	629	434	213	629	434	213	629	434	213

Note: Standard errors in parentheses; ***p < 0.01, **p < 0.05, *p < 0.1; NearParkArea: Area of the nearest park; NetworkDis: Road network distance to the nearest park; WaterArea300m: Water body area within 300m buffer from respondent' home; NearWaterDis: Euclidean distance to the nearest water body. All models control for the mode of survey, gender, age, education, occupation, marital status, residence location, and life event; Income levels: low is under 750$ per month; Median is between 750 and 1500$ per month; high is above 1500$ per month.

However, this relationship should be tested in other cities, best with pathway analysis since park size may be relevant for certain pathways that mitigate the association between greenspace and mental health, such as physical activity. It may not impact other pathways such as social cohesion, stress reduction, and attention restoration (Ekkel and de Vries, 2017).

Our study observed consistent multiple benefits from exposure to inland blue space, with even larger effect size than parks: a 1-ha increase of blue space within 300m of a residents' home will improve the MHI-5 score by 0.33%, and the negative affect score by

0.45%. However, this high value of blue space may not be generalized to coastal cities, as coastal ecosystems are perceived as being more attractive than inland water (White et al., 2013c), which may result in lower appreciation for inland water. A study in Catalonia, a coastal region in Spain, did not find a positive association between blue space and mental health (Triguero-Mas et al., 2015). The role of the cumulative area indicator (water area within a certain buffer) becomes non-significant when the buffer exceeds 300m. However, this positive association holds within larger buffers in other studies. For example, de Vries et al. (2003) and de Vries et al. (2016) found

Table 5
Stratified associations between park/blue space exposure and MHI-5 and subjective well-being by education.

Variables	MHI-5		Life satisfaction		Worthwhileness		Happy yesterday		Anxious yesterday	
	Lower	Higher	Lower	Higher	Lower	Higher	Lower	Higher	Lower	Higher
NearParkArea	**0.004****	**0.003****	0.003	0.002	**0.005***	0.002	**0.007****	0.002	0.004	0.003
	(0.002)	(0.001)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)	(0.003)	(0.002)
NetworkDis	−0.000	−0.000	0.000	−0.000	0.000	−0.000	0.000	−0.001	−0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.001)
R^2	0.179	0.108	0.200	0.193	0.160	0.215	0.216	0.147	0.245	0.123
WaterArea300m	**0.362***	0.219	**0.594****	−0.011	**0.517***	−0.196	**0.584***	0.090	0.441	0.345
	(0.204)	(0.220)	(0.278)	(0.283)	(0.287)	(0.290)	(0.308)	(0.345)	(0.349)	(0.410)
NearWaterDis	−0.000	0.001	0.000	0.001	−0.000	−0.000	−0.001	−0.002	**−0.003***	−0.001
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
R^2	0.177	0.100	0.203	0.191	0.161	0.214	0.216	0.147	0.252	0.123
Observations	649	625	650	626	650	626	650	626	650	626

Note: Standard errors in parentheses; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$; NearParkArea: Area of the nearest park; NetworkDis: Road network distance to the nearest park; WaterArea300m: Water body area within 300m buffer from respondent' home; NearWaterDis: Euclidean distance to the nearest water body. All models control for the mode of survey, gender, age, occupation, income, marital status, residence location, and life event. Lower education includes people attained degree lower than college; Higher education includes people attained college and graduate degree.

the amount of blue space within 3 km and 1 km buffer from a postcode centroid are associated with mental health in their respective study. A possible explanation for the difference is that Chinese people are only willing to travel short distances for recreation in nature. For example, (Liu et al., 2017b) found that a road network distance to parks within 500m is associated with park use. This low travel distance may be affected by other socioeconomic factors such as low car ownership or limited time for recreation (Liu et al., 2015). Given the multiple benefits observed in this study, blue space is a potential public health resource. Since the Guideline for Sponge City Construction issued by the General Office of the State Council in 2015, there is a national initiative to increase urban wetlands with the primary purpose of urban flood control (http://www.gov.cn/zhengce/content/2015-10/16/content_10228.htm). There is a call for high-quality studies to provide robust and actionable information (e.g., dose-response curve) to guide where to build the blue space to maximize the co-benefits. Guangzhou has large water surfaces (747 km^2 accounting for 10% of its area) indicating a potentially large but unrecognized mental health value which should be accounted for to justify the cost of blue space conservation practices.

Our study observed evident heterogeneity in the associations between nature exposure and mental health across gender. Women benefit more from nearby nature, which is consistent with previous findings (Gascon et al., 2018; Reklaitiene et al., 2014). The Chinese time-use survey reports that women spend more time purchasing daily goods, sending children to school, and playing with children, while men spend more time on work (Du et al., 2018). We suspect that the different gender roles of men and women may result in additional passive nature exposure for women compared with men. One similar hypothesis is that female homemaker may spend more time in their neighborhoods than working men (Ruijsbroek et al., 2017). Another possible explanation is that the psychophysiological responses between men and women differ. Roe et al. (2013) found that women in less green neighborhoods exhibit cortisol secretion patterns indicating higher exhaustion and stress than men in deprived communities. However, the cortisol secretion of both men and women in greener neighborhoods indicated better emotional regulation. Future research should explore the mechanism for the non-significant relationship in men to make effective interventions (e.g., programming in parks), in addition to providing a sufficient amount of nature.

Low-to-medium income and less-educated population were more susceptible to benefit from nearby nature in this study than their counterparts. This is consistent with previous

evidence—contact with nature may disproportionately benefit disadvantaged populations (Mitchell and Popham, 2007, 2008; Mitchell et al., 2015). Lower socioeconomic strata are more susceptible to mental stress and environmental hazards (e.g., noise pollution); thus, the protective effects may be more significant in these populations. For example, Korpela et al. (2008) and Rogerson et al. (2020) found that nature has stronger restorative effects on people experiencing greater emotional stress or stating lower initial mental health levels. In addition, lower socioeconomic strata may have lower mobility and they may spend more time in nearby public greenspace for recreation. Exploring the patterns of disproportionate access among different groups, their preferences, their experience of nature, and the pattern of benefits across socioeconomic groups and life course is essential to understand the diversity of the relationships between nature and mental health, and create effective interventions (Frumkin et al., 2017). Our cross-sectional evidence supports the need to promote greenspace programs in more deprived areas to maximize the returns of green investment, as well as reducing health inequity.

One strength of the present research is that we evaluated multiple mental health outcomes including the depression risk as well as four facets of SWB. This allowed for examination of specific components of mental health that nature exposure associates with. Protective effects were found in most mental health outcomes after controlling for confounders, which provided stronger evidence than single mental health measures. Secondly, our study examined the association of blue space with multiple mental health components which has been rarely assessed in the general Chinese population. Thirdly, we found consistent heterogeneous associations between nature exposure and all five mental health outcomes among population subgroups which was not explored in Chinese cities yet.

However, this study has some limitations. The relationship between nature and mental health is complex. Pathways that could mediate the relationship are not included and causality cannot be inferred in this study. High-quality evidence is lacking in developing countries and it requires long-term prospective or population-level experimental studies to provide robust science to guide practice (Shuvo et al., 2020). Moreover, our study only considered proximity and quantity of urban parks and blue space. Studies on different types (residential greenspace, street trees) and qualities of nature, types (nature view, visitation of different greenspace) and dose of natural exposure (physical activity, socializing, etc.) will provide more precise understanding for urban planning and programming design (Frumkin et al., 2017). Lastly, the

results found in this study may be confined to big and busy cities such as Guangzhou. Future studies should confirm and clarify these findings in different urban settings, such as medium and small cities, or coastal cities.

6. Conclusion

Empirical evidence concerning the degree to which nature might enhance mental health is required in Chinese cities to promote effective interventions in urban planning and management. We examined the associations between park/blue space exposure and multiple aspects of mental health and its heterogeneity in population subgroups in the Chinese city of Guangzhou. We have three main conclusions. First, both park and blue space exposure have protective effects on the population's mental health. Blue space has a larger effect size than parks with a 1-ha increase of blue space associating with 0.45% increase in mental health scores. Given the dense population in Guangzhou, the aggregate benefits at the population level could be substantial. Second, nature exposure associates differently with specific components of mental health. Park and blue space exposure were more consistently associated with lower depression risks and negative affect wellbeing. Varied associations were observed with positive affective, evaluative, and eudaimonic well-being. Achieving SWB across all its components requires access to both green and blue space. Third, heterogeneous associations between nature exposure and mental health exist in population subgroups. Compared to their counterparts, women, low-to-medium income, and less-educated population are inclined to gain more mental health benefits from nearby nature. This study highlights the importance of integrating nature's mental health benefits in urban planning and management in Chinese cities. However, such actions need to consider gender and socioeconomic differences to make effective interventions. Promoting nature in more deprived areas may help maximize the returns of green investments, as well as reducing health inequity.

CRediT authorship contribution statement

Hongxiao Liu: Conceptualization, Methodology, Writing — original draft, Formal analysis, Writing — review & editing. **Hai Ren:** Conceptualization, Methodology, Funding acquisition. **Roy P. Remme:** Methodology, Writing — review & editing. **Huifu Nong:** Conceptualization, Methodology, Resources, Software, Supervision. **Chunhua Sui:** Formal analysis.

Declaration of competing interest

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

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2021.127100.

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