



## Blue space exposure, health and well-being: Does freshwater type matter?

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### HIGHLIGHTS

- Freshwater blue space types can vary in their capacity to promote health and well-being.
- Living near lakes, rivers or canals was not associated with better general health or mental well-being.
- Frequently visiting rivers and canals was associated with higher mental well-being.
- Frequently visiting green space (but not blue space) increased the likelihood of reporting good general health.

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### ABSTRACT

There is growing evidence that spending time in or around water bodies or ‘blue spaces’ can result in improved human health. To date, investigations of the health-promoting potential of blue space exposure have mostly focused on coastal environments. Despite their vital role in many urban landscapes, freshwater blue spaces have received less research attention and very little is known about the potential of different freshwater blue space types to impact health and well-being. This study used logistic and negative binomial regression modelling to quantify the association between proximity and exposure to different freshwater blue space types and general health and mental well-being in Scotland. A nationwide online panel survey ( $n = 1392$ ) was used to determine how far respondents lived from lakes, rivers and canals and to establish how often they visited these blue spaces. Living within a ten minute walking distance of lakes, rivers or canals was not associated with greater general health or mental well-being. However, frequently visiting rivers and canals but not lakes, in the last month, was associated with greater mental well-being. Frequent green space visitation, but not blue space visitation, was associated with higher odds of reporting good general health. Taken together, our findings suggest that freshwater blue space exposure can provide mental well-being benefits. However, the provision of these benefits may vary among different freshwater blue space types. Understanding the health and well-being impact of different freshwater environments, therefore, offers opportunities for evidence-based policymaking to maximise the health-promoting potential of urban blue spaces.

### 1. Introduction

An extensive body of evidence suggests that contact between humans and the natural environment can result in a range of health and well-being benefits (Bratman et al., 2019; Frumkin et al., 2017; Hartig et al., 2014). Nature-health research has predominantly focused on the health-promoting potential of urban green space, which has been associated with a wide variety of physical and mental health benefits (Beyer et al., 2014; Gascon et al., 2016; Kondo et al., 2018). Consequently, strategies to improve green space accessibility and promote green space usage are becoming increasingly prominent in urban planning and

public health policy (Shanahan et al., 2015). There is also growing interest in the health-promoting potential of other elements of the natural environment, such as water bodies or ‘blue spaces’.

Blue spaces are defined as ‘outdoor environments – either natural or manmade – that prominently feature water and are accessible to humans’ (Grellier et al., 2017). It has been reported that exposure to blue space can result in improved health outcomes for both adults (Gascon et al., 2017; Smith, Georgiou, King, Tiegies, Webb, & Chastin, 2021) and children (Engemann et al., 2020). The mechanisms (or pathways) connecting blue space exposure to improved health outcomes are likely to be similar to those proposed for green space, e.g., promoting

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physical activity, social interaction, stress reduction and mental restoration. (Markevych et al., 2017; White, 2020). However, it has also been hypothesised that blue spaces offer a range of unique therapeutic and health-promoting properties (Foley & Kistemann, 2015; Völker & Kistemann, 2011).

To date, the majority of blue space and health research has focused on the health and well-being benefits of visiting or living in close proximity to the sea (coastal blue space) (Gascon et al., 2017). Visiting coastal blue space has been associated with improved mental well-being and reduced mental distress (White, 2021). Individuals who live in close proximity to the coast report more positive general health (Hooyberg et al., 2020) and mental health (White, 2013), reduced antidepressant medication usage (McDougall et al., 2021) and higher levels of physical activity (Pasanen et al., 2019) relative to individuals who live further inland. Furthermore, living in a residence with views of the sea can also result in improved mental health outcomes (Dempsey et al., 2018) and reduced symptoms of psychological distress (Nutsford et al., 2013).

Despite 50% of the global population living within 3 km of a body of freshwater (Kummu et al., 2011) and freshwater ecosystems being vital components of human settlements, the effects of freshwater blue space exposure on physical and mental health remain underexplored relative to marine environments. However, a small but growing evidence base suggests exposure to freshwater blue space can also lead to improved health outcomes (Völker & Kistemann, 2011). Visiting freshwater can lead to improved mental well-being and reduced mental distress (White, 2021) and people report high levels of happiness when spending time in or near freshwater (de Vries et al., 2021). Living in neighbourhoods with higher freshwater blue space availability has also been associated with increased likelihood of reporting positive mental health outcomes (Chen & Yuan, 2020; McDougall et al., 2021; Pasanen et al., 2019).

Although interest in the health-promoting potential of freshwater blue space is growing, empirical studies of the topic remain sparse, and a number of key knowledge gaps are yet to be investigated. Very little is known about the potential of different freshwater blue space types, such as lakes, rivers and canals, to promote health and well-being. Freshwater blue space types vary substantially in their physical and hydrological properties and offer different opportunities for recreation and usage (Mavoa et al., 2019). As such, freshwater blue space types will likely vary in their potential to facilitate pathways to improved health (e.g., physical activity and social interaction) and may, therefore, vary in their capacity to promote health and well-being (McDougall, 2020). Some ecological (area-level) studies have investigated the health and well-being effect of living in close proximity to canals (Tiegies et al., 2020) and lakes (Pearson, 2019). However, individual-level research investigating the health and well-being impact of exposure to multiple different freshwater blue space types, whilst controlling for exposure to other categories of the natural environment (e.g., coastal blue space and green space), is lacking.

The majority of blue space exposure and health studies adopt objective proxies for exposure, such as proximity to blue space or neighbourhood blue space coverage (Gascon et al., 2017). Such approaches are limited in their capability to quantify actual exposure (Helbich, 2018) or to establish varying levels of exposure to different blue space types. Self-reported accounts of blue space exposure, such as recalled visit frequency or contact time, offer an opportunity to quantify an individual's exposure to different freshwater blue space types in a way which captures the heterogeneity of individual exposure. Self-reported accounts of exposure are, therefore, well-suited to addressing a number of the aforementioned knowledge gaps in current freshwater blue space and health research.

Our study quantifies the association between multiple metrics of self-reported exposure to different freshwater blue space types (lakes, rivers and canals) and general health and mental well-being for a large sample of adults living in Scotland. The specific objectives were to (i) establish the impact of living in close proximity to different freshwater blue space types on self-reported general health and mental well-being; (ii)

quantify the association between freshwater blue space exposure, self-reported general health and mental well-being; and (iii) contextualise observed general health and mental well-being impacts relative to proximity and exposure to coastal blue space and green space.

## 2. Methodology

### 2.1. Study overview

A nationwide survey-based approach was used to quantify associations between proximity and exposure to freshwater blue space and self-reported general health and mental well-being. Logistic (general health) and negative binomial (mental well-being) regression modelling was used to determine associations between proximity and exposure to lakes, rivers and canals and both health outcomes. All analyses controlled for the potential effects of coastal blue space and green space exposure and a variety of individual and area-level covariates.

### 2.2. Sampling and recruitment

Survey respondents were recruited via an online panel provided by Qualtrics ([www.qualtrics.com](http://www.qualtrics.com)). Members of the online panel provide consent to participate in surveys and receive invitations to participate via email. Online panel surveying has been adopted in recent blue space (White, 2021) and nature exposure (Tester-Jones et al., 2020) and health research. A quota-based non-random sampling approach, which aimed to obtain a sample which aligned with the gender and age distribution of the population of Scotland, was adopted. Before gaining full access to the survey, panel members were subject to a screening process to ensure they were 18-years old or above and currently resided in Scotland.

### 2.3. Survey administration

The survey instrument (see Appendix 1) comprised three key sections, which are described in detail below; health and well-being (see Section 2.4); natural environment engagement (see Section 2.5) and background information (see Section 2.6). The survey instrument was pre-tested in seven focus groups across central Scotland. A 150-respondent pilot study was also conducted via Qualtrics, to test and refine the survey instrument. The main survey was active between 10th September 2021 and 23rd September 2021. During this period, minimal Coronavirus (COVID-19) restrictions were in place in Scotland. Legal requirements on physical distancing or gathering sizes were removed in early August 2021, although, some protective measures such as the use of face coverings in public indoor spaces remained in place.

### 2.4. Health and well-being outcomes

To increase the comparability of the results obtained in this study with the existing evidence base, validated instruments that have previously been adopted in blue space and health research were used to quantify mental well-being and general health (Gascon et al., 2017). Mental well-being was assessed using the World Health Organisation Five Well-being Index (known as WHO-5) (Topp et al., 2015). The WHO-5 has been used to explore associations between blue space exposure and mental well-being in a variety of different countries (Garrett et al., 2019; van den Bogerd et al., 2021; Vert et al., 2020; White, 2021). Survey respondents were asked to recall how often they experienced five positive emotional states in the past two weeks. Specifically, respondents were asked how often in the past two weeks; (i) they felt cheerful and in good spirits; (ii) they felt calm and relaxed; (iii) they woke up feeling fresh and rested; (iiii) they felt active and vigorous; and (v) their daily life had been filled with things that interest them. Respondents were asked to rate the frequency of experiencing each statement in the last two weeks on a six-point scale ranging from; 0 (At no time) to 5 (All of

the time). Respondent's scores for each positive emotional state were then combined and multiplied by four to produce a mental well-being score between 0 and 100 (Topp et al., 2015).

Self-reported general health was quantified using a single question 'How is your health in general?' (SF-1) which has previously been adopted in blue space and health research (Garrett et al., 2019; Hooyberg et al., 2020; Pasanen et al., 2019). Survey respondents were presented with five response options; (i) Very bad; (ii) Bad; (iii) Fair; (iiii) Good; and (v) Very Good. To account for a small number of respondents selecting the 'Very bad' health category ( $n = 13$ ), this data was transformed into two response types: good health (which combined 'Good' and 'Very Good' responses) and bad health (which combined 'Very bad', 'Bad' and 'Fair' responses). Several blue and green space exposure studies have adopted a similar dichotomisation of general health (Garrett et al., 2019; Hong et al., 2021).

## 2.5. Freshwater blue exposure

There remains no consensus on the most appropriate approach of quantifying exposure to blue space (Gascon et al., 2017). Consequently, three metrics of exposure; perceived proximity, visit frequency and contact time were adopted to assess associations with general health and mental well-being.

### 2.5.1. Perceived proximity

Survey respondents were asked which freshwater blue space types (canal, river and lake) were within a ten minute walk of their home. Walking time was preferred to distance-based proximity measures to account for differences in respondent's mobility and walking speeds (Völker, 2018). A walking time of ten minutes was selected to align with common definitions of neighbourhood size (Dalton et al., 2013) and because the likelihood of visiting freshwater blue space decreases when walking time exceeds ten minutes (Völker, 2018). Proximity models were adjusted for visit frequency to each freshwater blue space type.

### 2.5.2. Visit frequency

Respondents were presented with three freshwater blue space types (lakes, rivers and canals) and asked how many times they had visited each type in the last month. Visitation frequency to each freshwater blue space type was categorised as either; (i) 'Zero visits' – zero visits in the last month (reference category); (ii) 'Occasional visitor' – between one and three visits in the last month; or (iii) 'Frequent visitor' – greater than three visits in the last month. These categories were used to aid interpretation, as relationships between blue space visitation and health are often non-linear (White, 2021).

### 2.5.3. Contact time

Respondents were asked, based on the last month, how long an average visit to each freshwater blue space type lasted. Average visit times for each freshwater blue space type were multiplied by the frequency of visits to determine the number of hours a respondent spent in contact with each type in the last month. Contact time was categorised as either; (i) 'Zero hours' – zero hours of contact time in the last month (reference category); (ii) '>0–2 h' – between zero and two hours of contact time in the last month; and (iii) '>2 h' – greater than two hours of contact time in the last month. A threshold (or dosage) of two hours of nature contact time per week has been found to lead to improved health and well-being (White, 2019). However, this threshold was not adopted given our focus on contact times with multiple different types of blue space and green space. Furthermore, a recall period of a month was preferred to a one week recall period to ensure consistency with our measure of visit frequency.

## 2.6. Covariates

Our regression models included a number of important individual-

level and area-level covariates that have been associated with general health and mental well-being. However, it should be noted that our models do not control for all potential determinants of general health and mental well-being.

### 2.6.1. Coastal blue space and green space

The potential effects of coastal blue space and green space proximity, visit frequency and contact time on general health and mental well-being were controlled for in each regression model. In accordance with the metrics adopted for freshwater blue space, proximity models controlled for the presence or absence of coastal blue space or green space within ten minutes walking distance of a respondent's home. Models of visit frequency and contact time also adjusted for coastal blue space and green space visit frequency and contact time in the last month, using the same categories adopted for freshwater blue space.

### 2.6.2. Individual-level covariates

In accordance with previous blue and green space exposure research, all models were adjusted for several demographic and socioeconomic covariates which have been shown to cause variations in health and well-being. These included age, gender, household income, educational status, marital status, dog ownership and car ownership (de Bell et al., 2017; Garrett et al., 2019; Pasanen et al., 2019; Poulsen et al., 2022). The analysis adjusted for the presence of long-limiting illness, which has been shown to reduce visitation to natural environments (Boyd et al., 2018). Given the established relationship between mental well-being and general health, WHO-5 was included as a determinant of general health, and general health score as a determinant of WHO-5 (Garrett et al., 2019). The potential health and well-being effects of physical activity (Penedo & Dahn, 2005) and social interaction (Day, 2008) were also adjusted for. Respondent's 'moderate' and 'vigorous' physical activity levels during the last week were obtained via the Short Form International Physical Activity Questionnaire (IPAQ-SF). Respondents were then classified as either meeting or failing to meet the WHO physical activity guidance for adults of 150 mins of moderate or 75 min of vigorous physical activity per week (WHO, 2020). Social interaction was quantified as the self-reported number of days within the last two weeks that a respondent had 'met up' with a friend or neighbour (Maas et al., 2009). Analyses also controlled for negative impacts of COVID-19 on household income, which has been associated with deteriorations in health and well-being (Yue & Cowling, 2021).

### 2.6.3. Area-level covariates

A number of self-reported area-level covariates which have previously been associated with health and well-being were controlled for, including neighbourhood air pollution (Manisalidis et al., 2020) and noise annoyance (Basner et al., 2014). In accordance with Dzhambov et al. (2018) respondents were asked to what extent their neighbourhood air was polluted and to what extent they were bothered by noise outside their home. For each question, respondents were presented with an eleven-point response scale ranging from; 0 (not at all) to 10 (extremely). The analysis also adjusted for potential health and well-being effects of urbanicity (Zijlema, 2015). The urbanicity of each respondent's postcode was determined based on the Scottish Government Urban Rural Classification, which defines urban and rural areas as communities with populations > 3,000 people and < 3,000 people, respectively.

## 2.7. Statistical analysis

All statistical analyses were carried out in Stata (version 16.1) (College Station, USA). Given the count nature of the dependent variable (WHO-5), associations between mental well-being and freshwater blue space proximity and exposure were analysed using negative binomial regressions. Overdispersion was observed in the data and Poisson regression was, therefore, unsuitable (Hilbe, 2011). Associations

between mental well-being and independent variables were reported as Incidence Rate Ratios (IRRs) with 95% Confidence Intervals (CIs). Multiple logistic regression was used to analyse associations between general health and freshwater blue space proximity and exposure. Associations were reported as Odds Ratios (OR) with 95% CIs.

In total, six models were developed to analyse associations between perceived proximity to each freshwater blue space type, visit frequency, contact time and general health and mental well-being. These models were; 1) perceived proximity and mental well-being; 2) perceived proximity and general health; 3) visit frequency and mental well-being; 4) visit frequency and general health; 5) contact time and mental well-being; and 6) contact time and general health. All models were adjusted for a variety of individual and area-level covariates, which were hypothesised to impact general health and mental well-being. Variables included in each model are reported in Table 1 and a full description of each variable is provided in Supplementary Table 1. The inclusion of each variable was justified by evaluating Akaike information criterion (AIC) and Bayesian information criterion (BIC) to identify the best fitting and most parsimonious model. A number of variables including local authority area, area-level deprivation, the number of children in the household and employment status reduced model performance and were excluded. Variance inflation factors (VIF) were analysed in the development of each model to identify multicollinearity.

### 3. Results

#### 3.1. Descriptive statistics

In total, the online panel survey was completed by 1511 respondents. The final sample consisted of 1392 respondents once those with missing data ( $n = 119$ ) were removed. Most respondents who were removed from the sample failed to provide a full postcode, which prevented further analysis. The socioeconomic and demographic profile of respondents who were removed from further analysis did not differ from

**Table 1**  
Summary of socioeconomic and demographic statistics of sample.

Variable	Category	Number / frequency	Mean / % of total	SD
Mental Well-being (0–100)	–	1392	51.12	24.0
General Health	Good	796	57.2	
	Bad	596	42.8	
Ill Health	Yes	338	24.3	
	No	1054	75.7	
Gender	Male	585	42.0	
	Female	807	58.0	
Age	–	1392	46.2	15.2
Household Income	–	1392	36,791	21,384
COVID-19 Impacted Income	Yes	424	30.5	
	No	968	69.5	
WHO Weekly Exercise	Yes	486	34.9	
	No	906	56.1	
Relationship Status	Yes	868	62.4	
	No	524	37.6	
Education Status	Yes	541	38.9	
	No	851	61.1	
Social Interaction (0–14)	–	1392	4.1	4.3
Dog Ownership	Yes	496	35.6	
	No	896	64.4	
Car Ownership	Yes	1027	73.8	
	No	365	26.2	
Noise Annoyance (0–10)	–	1392	4.2	2.9
Air Pollution (0–10) Urbanicity	–	1392	4.1	2.6
	Rural	1203	86.4	
		189	13.6	

the final sample. Table 1 summarises the socioeconomic and demographic statistics of the final sample. The mean mental well-being (WHO-5) score of the sample was 51.1 (SD 24.0) and the majority (57.2%) of respondents reported good general health. As a result of the quota-based sampling approach, the sample broadly reflected the national population of Scotland in terms of age and gender. The sample was composed of 817 females (58%) and 585 males (42%), which aligns with the female majority (52%) in the adult population (National Records of Scotland, 2019). The mean age of the sample was 46-years old, which is slightly above the national median age of 42-years old (National Records of Scotland, 2019). In the week prior to completing the survey, the majority (66.1%) of respondents did not meet WHO recommendations for moderate and vigorous physical activity.

Table 2 summarises perceived proximity to each type of blue and green space and visit frequencies and contact times for each type in the month prior to completing the survey. Approximately 10% of the sample lived within 10-minutes walking distance of a lake (10.9%), canal (10.3%) or the sea (14%) and around a third (30.2%) of respondents reported living within a 10-minute walk of a river. The majority (76.3%) of respondents lived with a 10-minutes walking distance of a green space.

Varied patterns of visitation were reported for each freshwater blue space type. Slightly less than half of respondents had visited a river (44.3%) or the sea (45.1%) in the last month and 20.1% and 17.7% of respondents visited these environments frequently (more than three times). Considerably lower numbers of respondents reported visits to lakes (31.4%) or canals (17.7%) in the last month. Around 20% (21.2%) of the sample visited lakes occasionally (between one and three times in the last month), whilst 142 respondents (10.2%) visited lakes frequently. Over 80% (82.2%) of the sample made at least one green space visit in the last month and 59.7% of the sample reported frequent green space visitation.

Self-reported contact time with each blue space type and green space was similar to patterns observed for visit frequency. Around 10% of respondents reported contact times of more than two hours with canals (7%) and lakes (13.1%) in the last month. Approximately 20% of the sample reported contact times of more than two hours with rivers (20.2%) and the sea (24.4%). More than half of respondents (56%) had visited green spaces for more than two hours in the last month.

#### 3.2. Perceived proximity

The results of the negative-binomial (mental well-being) and logistic (general health) regression models focusing on proximity to each blue space type are presented in Table 3. Living near (within 10 min walking distance) a canal, lake or river had no significant association with mental well-being as measured by the WHO-5 scale. Living near to lakes and canals was associated with higher mental well-being, although, these associations were not significant ( $p > 0.05$ ). No significant associations were observed between general health and living within 10-minutes walking distance of rivers, canals, lakes, green spaces or the sea.

#### 3.3. Visit frequency

The results of the negative-binomial (mental well-being) and logistic (general health) regression models focusing on visitation to each blue space type and green space in the last month are presented in Table 4. No significant associations were observed between mental well-being and the number of visits a respondent made to lakes or green spaces in the last month. Frequent visitation (more than twice in the last month) to rivers (IRR 1.07; 95% CI 1.01–1.13;  $p < 0.05$ ) and canals (IRR 1.09; 95% CI 1.01–1.19;  $p < 0.05$ ) was associated with higher mental well-being scores relative to respondents who did not visit rivers and canals. However, no significant differences were observed between the mental well-being scores of respondents who did not visit rivers or canals and respondents who visited rivers and canals only occasionally (1–2 times

**Table 2**  
Summary statistics of proximity and exposure to each blue space type and green space.

Variable	Category	Frequency	% of total
Lake (10-minute walk)	Yes	151	89.1
	No	1241	10.9
River (10-minute walk)	Yes	421	30.2
	No	971	69.8
Canal (10-minute walk)	Yes	143	10.3
	No	1249	89.7
Sea (10-minute walk)	Yes	195	14.0
	No	1197	86.0
Green Space (10-min walk)	Yes	1062	76.3
	No	330	23.7
Lake Visits	Zero Visits	955	68.6
	Occasional Visitor	295	21.2
	Frequent Visitor	142	10.2
River Visits	Zero Visits	775	55.7
	Occasional Visitor	337	24.2
	Frequent Visitor	280	20.1
Canal Visits	Zero Visits	1146	82.3
	Occasional Visitor	160	11.5
	Frequent Visitor	86	6.2
Sea Visits	Zero Visits	764	54.9
	Occasional Visitor	382	27.4
	Frequent Visitor	246	17.7
Green Space Visits	Zero Visits	248	17.8
	Occasional Visitor	313	22.5
	Frequent Visitor	831	59.7
Lake Contact Time	Zero	977	70.2
	>0–2 h per month	232	16.7
	>2 per month	183	13.1
River Contact Time	Zero	793	57.0
	>0–2 h per month	318	22.8
	>2 per month	281	20.2
Canal Contact Time	Zero	1158	83.2
	>0–2 h per month	137	9.8
	>2 per month	97	7.0
Sea Contact Time	Zero	792	56.9
	>0–2 h per month	260	18.7
	>2h per month	340	24.4
Green Space Contact Time	Zero	270	19.4
	>0–2 h per month	287	20.6
	>2h per month	835	56.0

in the last month). Relative to respondents who had not visited the sea in the last month, respondents who had visited the sea occasionally (IRR 1.07; 95% CI 1.02–1.14;  $p < 0.01$ ) and frequently (IRR 1.06; 95% CI 1.01–1.12;  $p < 0.01$ ) reported higher mental well-being scores. However, no significant associations were observed between visiting any blue space type and general health. Respondents who visited green spaces frequently were over two times more likely to report good health (OR 2.01; 95% CI 1.30–3.11;  $p < 0.01$ ) than respondents who had not visited a green space in the last month.

**Table 3**  
Model of proximity to blue and green space, mental well-being and general health displayed as Incidence Rate Ratios (IRRs) and Odds Ratios (ORs) with 95% Confidence Intervals (CIs). See supplementary Tables 2 and 3 for full model specification.

Variable	Mental Well-being		General Health	
	IRR	95% CI	OR	95% CI
Lake Proximity	1.012	0.935–1.095	0.937	0.587–1.495
River Proximity	0.978	0.926–1.032	1.435	1.012–2.035
Canal Proximity	1.072	0.988–1.163	0.798	0.471–1.353
Sea Proximity	1.018	0.942–1.099	0.877	0.578–1.328
Green Space Proximity	1.027	0.967–1.09	1.084	0.76–1.545

\*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ .

Models adjusted for ill-health, gender, age, household income, COVID-19 impact on income, physical activity, relationship status, education status, weekly interaction, dog ownership, car ownership, neighborhood noise annoyance, neighborhood air pollution, urbanicity and blue and green space visits.

**Table 4**  
Model of visit frequency to blue and green space, mental well-being and general health displayed as Incidence Rate Ratios (IRRs) and Odds Ratios (ORs) with 95% Confidence Intervals (CIs). See supplementary Tables 4 and 5 for full model specification.

Variable	Mental Well-being		General Health	
	IRR	95% CI	OR	95% CI
Lake Visits (zero)	(ref)	.	(ref)	.
Lake Visits (occasional)	1.022	0.967–1.079	1.12	0.758–1.656
Lake Visits (frequent)	1.031	0.96–1.107	0.803	0.502–1.283
River Visits (zero)	(ref)	.	(ref)	.
River Visits (occasional)	1.047	0.988–1.11	0.781	0.544–1.122
River Visits (frequent)	<b>1.065*</b>	1.003–1.132	0.827	0.544–1.257
Canal Visits (zero)	(ref)	.	(ref)	.
Canal Visits (occasional)	1.063	0.994–1.137	0.913	0.571–1.459
Canal Visits (frequent)	<b>1.095*</b>	1.007–1.19	0.766	0.401–1.463
Sea Visits (zero)	(ref)	.	(ref)	.
Sea Visits (occasional)	<b>1.078**</b>	1.022–1.136	0.908	0.643–1.283
Sea Visits (frequent)	<b>1.06**</b>	1.003–1.122	1.014	0.672–1.532
Green Space Visits (zero)	(ref)	.	(ref)	.
Green Space Visits (occasional)	1.032	0.949–1.123	1.499	0.952–2.359
Green Space Visits (frequent)	1.009	0.934–1.09	<b>2.017**</b>	1.305–3.117

\*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ .

Models adjusted for ill-health, gender, age, household income, COVID-19 impact on income, physical activity, relationship status, education status, weekly interaction, dog ownership, car ownership, neighborhood noise annoyance, neighborhood air pollution and urbanicity.

### 3.4. Contact time

Negative-binomial (mental well-being) and logistic (general health) regressions focusing on contact time with each blue space type and green space in the last month were derived (Table 5). The contact time models displayed broadly similar results to those focusing on associations between visit frequency and both health outcomes. No significant associations were observed between mental well-being and contact time in the last month with either lakes, rivers or green spaces. However, respondents who reported contact times with canals of over two hours in the last month reported significantly higher mental well-being scores (IRR 1.10; 95% CI 1.02–1.91;  $p < 0.05$ ) than individuals who reported no contact time with canals. No significant association was observed between individuals who did not report any contact time with canals and respondents who reported between zero and two hours of contact time. Respondents who had visited the sea for over two hours in the last month reported higher mental well-being scores (IRR 1.058; 95% CI 1.01–1.12;  $p < 0.05$ ) than respondents who reported no contact time with the sea over this period.

**Table 5**

Model of contact time with blue and green space, mental well-being and general health displayed as Incidence Rate Ratios (IRR) and Odds Ratios (OR) with 95% Confidence Intervals (CIs). See Supplementary Table 6 and 7 for full model specification.

Variable	Mental Well-being		General Health	
	IRR	95% CI	OR	95% CI
Lake Time (zero)	(ref)	.	(ref)	.
Lake Time (>0–2 h)	1.049	0.989–1.113	1.233	0.797–1.907
Lake Time (>2 h)	1.024	0.96–1.092	0.862	0.556–1.336
River Time (zero)	(ref)	.	(ref)	.
River Time (>0–2 h)	1.032	0.975–1.092	0.914	0.632–1.323
River Time (>2 h)	1.054	0.989–1.124	0.886	0.584–1.343
Canal Time (zero)	(ref)	.	(ref)	.
Canal Time (>0–2 h)	1.037	0.965–1.114	1.035	0.617–1.737
Canal Time (>2 h)	<b>1.099*</b>	1.014–1.191	0.666	0.369–1.204
Sea Time (zero)	(ref)	.	(ref)	.
Sea Time (>0–2 h)	1.052	0.992–1.117	0.842	0.573–1.238
Sea Time (>2 h)	<b>1.058*</b>	1.003–1.116	1.033	0.718–1.486
Green Space Time (zero)	(ref)	.	(ref)	.
Green Space Time (>0–2 h)	1.047	0.964–1.137	1.319	0.836–2.08
Green Space Time (>2 h)	1.016	0.944–1.093	<b>1.572*</b>	1.037–2.382

\*\*\*  $p < 0.001$ , \*\*  $p < 0.01$ , \*  $p < 0.05$ .

Models adjusted for ill-health, gender, age, household income, COVID-19 impact on income, physical activity, relationship status, education status, weekly interaction, dog ownership, car ownership, neighborhood noise annoyance, neighborhood air pollution and urbanicity.

No significant association was observed between contact time in the last month with any blue space type and self-reported general health. However, respondents who spent more than two hours visiting green spaces in the last month were more likely to report good health (OR 1.57; 95% CI 1.04–2.38;  $p < 0.05$ ) than individuals who reported no contact with green space. The likelihood of reporting good general health status did not differ significantly between those who reported zero hours of contact time with green space in the last month and those who reported between zero and two hours of contact time.

## 4. Discussion

### 4.1. Overview

Our study examined the relationship between proximity and exposure to multiple freshwater blue space types and self-reported general health and mental well-being. Our analyses controlled for proximity and exposure to coastal blue space and green space and for a variety of individual and area-level covariates that can also impact health and well-being. Our findings suggest that frequently visiting rivers, canals and the sea, but not green spaces or lakes, is associated with greater mental well-being. Frequently visiting green spaces, but no type of blue space, increases the likelihood of reporting better general health. Our findings also suggest spending more than two hours per month in contact with canals and the sea is associated with greater mental well-being relative to individuals who spend no time in these settings.

### 4.2. Principal findings

Of the three freshwater blue space types considered in our analysis, only exposure to rivers and canals was associated with greater mental well-being. No association was observed between exposure to lakes and mental well-being or exposure to any freshwater blue space type and general health. These findings highlight the potential of different freshwater blue space types to vary in their contribution to improved health and well-being. Findings from studies that combine multiple freshwater blue space types into a single category should, therefore, be interpreted with a degree of caution, as such approaches may not fully reveal the health and well-being effects of exposure to each freshwater

blue type on the study population. An improved understanding of the health and well-being benefits from exposure to different freshwater blue space types within an area of interest (e.g., on a city scale) offers opportunities to prioritise investment and for evidence-based urban planning and delivery of public health policies to maximise the health and well-being benefits offered by freshwater environments.

Respondents who frequently visited canals and rivers reported 9% and 7% higher mental well-being (WHO-5) scores than respondents who did not visit these environments. When contextualised alongside our control variables, the relative value of freshwater blue space as a health-promoting resource is apparent. For example, respondents who achieved the WHO recommendations for physical activity in the last seven days, reported 12% higher WHO-5 scores than respondents who did not meet these recommendations. The benefits for mental well-being of frequent canal and river visitation are smaller, yet comparable to the well-being benefits of meeting WHO physical activity guidance, which has well established associations with physical and mental health and plays an important role in global public health policy (WHO, 2020). Indeed, our findings may have particular public health importance as protecting and promoting positive mental well-being (or positive mental health) can play an important role in public health strategies to reduce mental illness (Keyes, 2014).

Of the freshwater blue space types considered in our analysis, frequent visitation to canals had the greatest positive impact on mental well-being. Spending time on and around canals may be particularly suited to improved mental well-being as these environments can facilitate relaxation and stress reduction (Vaeztavakoli et al., 2018). Canals can also provide opportunities for physical activity, social interaction and are valued for their ability to provide access to nature in dense urban settings and buffer harmful conditions often present in urban environments, e.g. road traffic noise (Smith, Georgiou, King, Tiegies, & Chastin, 2022). Interestingly, public preference data suggest the amenity value of canals is lower than other freshwater blue space types (Haefner et al., 2017). Canals in the UK can also be perceived negatively due to associations with uncleanliness and antisocial behaviour (Pitt, 2018). Nevertheless, our findings reinforce suggestions that canals can be health-promoting assets in urban areas (Smith, Georgiou, King, Tiegies, & Chastin, 2022).

Frequently visiting rivers was also associated with greater mental well-being. Riverside locations may be particularly restorative as they can facilitate exposure to the sound of flowing water (Milligan & Bingley, 2007). Improved health and well-being may also be explained by the active recreational opportunities e.g., walking, running and cycling (Vert et al., 2019) and passive recreational opportunities associated with riverside visits e.g., relaxing while watching the flow of water or 'people-watching' (Völker & Kistemann, 2013). Although our data suggests frequently visiting rivers is associated with greater mental well-being, unlike canals and the sea, this relationship was not observed when contact time in the last month was considered. Whilst identifying dose–response relationships is beyond the scope of this research, our findings tentatively indicate different dose–response relationships among blue space types (Shanahan et al., 2015).

Our analysis did not identify any significant associations between simply living near lakes or self-reported exposure to lakes in the last month and mental well-being or general health. This result was unexpected, as lakes provide a wide variety of ecosystem services, unique recreational opportunities and are viewed as landscape components that are particularly important for health and well-being (Elbakidze et al., 2017). Furthermore, living in close proximity to large lakes has been associated with lower antidepressant medication usage in Scotland (McDougall et al., 2021). There are some potential explanations for this finding. Firstly, it has been suggested that living in close proximity to large, but not small lakes, is associated with improved mental health outcomes (Pearson, 2019). Our study did not consider lake size, which may play an important role in the provision of health and well-being benefits, as larger lakes may be more likely to attract investment and

generally be of greater blue space quality and, consequently, more likely to positively impact health and well-being (McDougall et al., 2021). Secondly, although our analysis adopted a relatively coarse control for urbanicity, lakes in Scotland are rarely located in urban environments, unlike rivers and canals. Urban waterways often provide an 'escape' from harmful urban conditions (e.g., road traffic noise) (Smith, Georgiou, King, Tiegies, & Chastin, 2022) and in Scotland this may be less likely to be the case for lakes, which could explain the greater mental well-being impact observed for river and canal visitation in our sample. However, these potential explanations are speculative and further research on the effect of proximity and exposure to lakes on health and well-being is an important area for future study.

#### 4.3. Blue space, green space and health

Despite only identifying significant associations between two of the three freshwater blue space types considered in our analysis and mental well-being, our findings corroborate suggestions that freshwater blue space exposure can promote health. Our findings align with a recent study which found an association between visiting freshwater blue space within the last month and lower psychological distress and higher mental well-being across eighteen countries, including the UK (White, 2021). Völker (2018) also found that frequent freshwater blue space visitation was associated with higher mental health in Germany. Indeed, mental well-being benefits are viewed as one of the most important benefits of visiting freshwater blue spaces (de Bell et al., 2017). Three key pathways are likely to mediate these mental well-being benefits. These include (i) harm reduction, whereby freshwater blue space leads to the reduction of detrimental environmental conditions such as noise or excessive urban heat; (ii) capacity building, whereby freshwater usage increases the likelihood of social interactions and physical activity; and (iii) capacity restoration, whereby exposure to freshwater facilitates and promotes cognitive restoration, stress reduction and relaxation (Markevych et al., 2017; White, 2020). The contribution of each pathway to improved health and well-being may vary among different freshwater blue space types (McDougall, 2020); however, our sample was not of sufficient size to conduct mediation analysis.

Our findings suggest a mixed relationship between blue and green space exposure, mental well-being and general health. Proximity or exposure to freshwater or coastal blue space was not associated with general health. However, respondents who occasionally or frequently visited green spaces or reported more than two hours of contact time with green spaces in the last month were more likely to report good general health. Garrett et al. (2019) also found green space, but not blue space, visitation to be associated with greater odds of reporting good general health in a study of older adults. Collectively, these findings suggest green space exposure may be more suited to general health promotion than blue space exposure. Green space may be more likely than blue space to reduce environmental harms related to physical health outcomes e.g., air pollution (Wang et al., 2020) and exposure to green space has been associated with a variety of improved physical health outcomes including reductions in high blood pressure, improved cardiovascular health and reduced mortality (Twohig-Bennett & Jones, 2018). Very little evidence suggests an association between physical and cardiovascular health outcomes and blue space exposure (Gascon et al., 2017), which may explain why only green space exposure was associated with general health in our sample.

Unlike canals, rivers and the sea, greater green space exposure in the last month was not associated with higher mental well-being. Higher mental well-being has been associated with increased blue space visitation, but not green space visitation, in urban settings in Germany (Völker, 2018) and Hong Kong (Garrett et al., 2019). Whilst Nutsford et al. (2013) found blue space visibility from one's home, but not green space visibility, was associated with reduced psychological distress in Auckland, New Zealand. Our findings add to a growing body of literature that suggests blue space exposure may be more beneficial for

mental well-being than green space exposure. Indeed, environmental psychology research suggests blue spaces are preferred to green spaces and are more likely to promote feelings of happiness (White, 2010). Blue spaces may also be more suited to promoting stress reduction and relaxation relative to other natural environments (Finlay et al., 2015), whilst also offering unique therapeutic opportunities (Foley, 2015). Although a number of studies have suggested blue space exposure may provide greater mental well-being benefits than green space exposure, evidence of this relationship remains tentative (Pasanen et al., 2019). Furthermore, it should be noted that our study did not account for a variety of green space metrics that may be associated with mental well-being e.g., green space type, green space quality or residential greenness (Lee & Maheswaran, 2011).

#### 4.4. Policy implications

The findings of our study offer a number of valuable implications for urban planning, landscape design and public health policy. There is a need for freshwater blue space to receive greater consideration as a resource that can promote health and well-being; however, policy makers should be aware of the potential for different freshwater types to vary in their contribution to health promotion. Social media, sports tracking and mobile data offers a cost-effective opportunity for policy makers to better understand how, when and by whom different freshwater blue space types are used (Heikinheimo et al., 2020). This is important, since our findings suggest that intentional exposure is more relevant than mere residential proximity for mental well-being. Our findings may be particularly timely given that exposure to blue space can offer a buffer to many of the negative mental health impacts of COVID-19, such as 'lockdown' restrictions (Pouso et al., 2021). Strategies to increase freshwater blue space access offer scope to attain public health benefits and, where possible, should be coupled alongside the provision of a variety of other freshwater ecosystem services.

Whilst increased blue space accessibility is important, policymakers also face the challenge of addressing inequities in blue space usage (de Bell et al., 2017). For example, although low-income and Hispanic residents of Utah live closer to blue spaces, high-income and white residents are more likely to visit blue spaces (Haefner et al., 2017). Crucially, policymakers should ensure strategies to increase blue space usage mitigate potentially negative health impacts e.g., increased exposure to harmful algal blooms or increased water-related fatalities. The possibility of negative socioeconomic outcomes as a result of improved blue space provision or quality, such as blue (environmental) gentrification, should also be also considered (Anguelovski et al., 2018).

#### 4.5. Strengths, limitations and future work

By considering multiple freshwater blue space types, our approach addresses a key knowledge gap related to freshwater blue space and health and provides empirical data to reinforce suggestions that different freshwater blue space types may vary in their health-promoting potential. Our use of validated tools for quantifying general health and mental well-being, which have been previously adopted in blue space and health research, allows for close comparability to other studies (Gascon et al., 2017). By adopting self-reported contact time and visitation to freshwater blue space in the last month, our study was able to account for actual exposure to these environments and was not restricted to proxies of exposure, overcoming a common limitation of nature-health research (Helbich, 2018). Finally, our study controlled for a wide variety of established and emerging individual and area-based covariates which have been associated with general health and mental well-being, including the negative effects of COVID-19 on household income.

Our study was also subject to limitations, many of which offer opportunities for future research. Although our sample was representative of the population of Scotland in terms of age, gender and household

income, the non-random sampling approach adopted in this study may limit the generalisability of our findings. Additionally, our online panel surveying approach prevented gathering information on individuals who declined to participate in the survey, potentially introducing non-response bias (Boyle, 2016). The cross-sectional design of our study does not allow causation to be established and longitudinal studies of freshwater blue space exposure, health and well-being offer scope to better understand causality (Gascon et al., 2017). Furthermore, our analysis did not account for differences in blue space quality (e.g., accessibility, water quality or perceptions of safety), which can influence the potential of a blue space to positively impact health (Mishra et al., 2020). Research examining the health and well-being effects of exposure to different freshwater blue space types, whilst controlling for differences in blue space quality in these environments, offers an interesting area of future study. Another limitation of our study is the short period of time in which survey responses were collected. Multi-seasonal research can account for differences in weather and freshwater visitation patterns (White, 2021) and it may be of particular interest to replicate our investigation during winter when freshwater environments in Scotland are likely to freeze and when daylight and, consequently, feelings of safety around blue spaces is reduced (Smith, Georgiou, King, Tiegies, & Chastin, 2022). Our study only considered proximity and exposure to three freshwater blue space types. Although, these are the three most common freshwater blue space types found in landscapes across Scotland, investigations of the health and well-being effects of exposure to less common freshwater blue space types (e.g., waterfalls, wetlands and fountains) offers scope to build upon our findings. Finally, freshwater blue space contact time and visit frequency were self-reported based on a recall period of month prior to survey completion. Our exposure data may, therefore, be subject to error and self-reporting bias and our analysis could not account for different distributions of exposure across the recall period, which could have an impact on our measured health outcomes.

## 5. Conclusion

Our study examined the relationship between proximity and exposure to multiple freshwater blue space types, general health and mental well-being in Scotland, whilst controlling for a range of individual and area-based covariates. The findings suggest that frequently visiting rivers, canals and the sea, but not lakes, is associated with greater mental well-being. Whilst frequently visiting green space, but not freshwater or coastal blue space, is associated with greater likelihood of reporting good general health. Our results contribute towards a growing body of evidence that suggests exposure to freshwater blue space can play an important role in promoting mental health and well-being. Importantly, our data reinforces suggestions that freshwater blue space types may – but not always – vary in their impact on health and well-being. Understanding the health and well-being benefits attained from exposure to different freshwater environments, therefore, offers opportunities for evidence-based policymaking to maximise the health-promoting potential of urban blue spaces.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.landurbplan.2022.104446>.

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