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Titel | Title

High Quality Waters Run Deep. The Effect of Blue Space Type and Quality on Psychological Restoration and Nature Connectedness.

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Abstract

Blaue Infrastruktur (d.h. alle natürlichen oder anthropogenen Gewässer und ihre unmittelbare Umgebung) hat in letzter Zeit aufgrund ihrer positiven Assoziationen mit Gesundheit und Wohlbefinden ein erhöhtes Forschungsinteresse erlangt. Diese Forschung ist angesichts der Urbanisierungstendenzen, der anhaltenden psychischen Gesundheitskrise und der Tatsache, dass sich Städte historisch an Gewässern gebildet haben, besonders relevant. Wichtige Merkmale von - und Unterschiede zwischen - verschiedenen Arten von Gewässern, die positive Auswirkungen haben könnten, sind jedoch noch nicht ausreichend geklärt. Für die vorliegende Arbeit wurde ein großer (N = 14393), repräsentativer Datensatz aus 19 Ländern verwendet, stammend aus einem Online-Fragebogen über den letzten Gewässer-Besuch der Teilnehmer*Innen in den letzten vier Wochen. Mithilfe linearer gemischter Modelle untersuchte diese Studie die Beziehung zwischen dem besuchten Gewässer, der wahrgenommenen Umgebungsqualität und der psychologischen Restoration (einem Gefühl der Entspannung/Erfrischung) und Naturverbundenheit (einer emotionalen oder kognitiven Bindung zur Natur), die die Teilnehmer*Innen aus ihrem Besuch gewinnen konnten, unter Berücksichtigung wichtiger soziodemografischer Variablen. Verschiedene Gewässer wurden zunächst nach hydrologischen Definitionen in drei Kategorien (stehende Binnengewässer, fließende Binnengewässer und Meeresgewässer) eingeteilt - ein Novum in der Forschung zu blauer Infrastruktur und Gesundheit im Sinne der Vergleichbarkeit und künftiger Wissenssynthese. Eine höhere Umgebungsqualität stand in Zusammenhang mit verbesserter Restoration und Naturverbundenheit, unabhängig von der Art des Gewässers. Darüber hinaus standen fließende Gewässer in Verbindung mit höherer Restoration, während Meeresgewässer sowohl höhere Restoration als auch Naturverbundenheit mit sich brachten. Dieser Beitrag zu einem weitgehend übersehenen Thema in der Forschung zu blauer Infrastruktur veranschaulicht die Bedeutung von qualitativ hochwertigen Gewässern und welche Stärken verschiedene Gewässer aufzeigen können. Ein tieferes Verständnis über blaue Infrastruktur und ihre Auswirkungen auf Wohlbefinden kann Initiativen für Stadtplanung verbessern und die Lebensqualität großer Bevölkerungsgruppen steigern.

English Abstract

Blue spaces (i.e. any natural or anthropogenic bodies of water and their direct surroundings) have recently gained increased attention regarding their positive associations with health and well-being. This research is especially relevant in view of urbanization trends, the continuing mental health crisis, and the fact that cities have historically developed around bodies of water, which therefore play a vital role in their landscapes. However, important characteristics of, and differences between, blue spaces that might facilitate beneficial effects remain understudied.

The present work utilized a large (*N* = 14393), representative dataset from 19 countries, stemming from an online questionnaire about participants' most recent visit to a blue space in the last four weeks. Using linear mixed models, this study investigated the relationship between a visited blue space, perceived quality, and psychological restoration (i.e. feeling relaxed/refreshed) and connectedness to nature (i.e. an emotional or cognitive bond to nature) that people gained from their visit, while controlling for important sociodemographic variables. Various blue spaces were initially grouped into three blue space types (inland standing water, inland flowing water, and marine environments) according to hydrological/limnological definitions, a first in blue space and health research with the aim to improve comparability and future synthesis.

Higher perceived quality was positively associated with improved restoration and nature connectedness, regardless of blue space type. Furthermore, inland flowing water environments were associated with higher restoration, and marine environments were linked to both increased restoration and nature connectedness. This work contributes to a largely overlooked topic in blue space research, highlighting the importance of high-quality blue spaces, as well as strengths of different blue space types. Through improving the understanding of blue spaces and their effects on well-being, urban planning initiatives can be more informed and improve the quality of life of large populations.

Keywords: blue space, nature quality, restoration, connectedness to nature, blue health

High Quality Waters Run Deep.

The Effect of Blue Space Type and Quality on Psychological Restoration and Nature Connectedness.

With a continuing trend of rapid urbanization (United Nations, 2019), as well as the persisting high prevalence of mental illness in high-income countries (World Health Organization, 2017), an increasing amount of research notes the importance of accessible natural environments for their numerous associated health benefits (Frumkin et al., 2017; White et al., 2021). It has been estimated that two-thirds of the world's population will live in cities by 2050 (United Nations, 2019). Concurrently, characteristics of urban living have been linked to higher rates of chronic non-communicable diseases and obesity (Goryakin et al., 2017), and poor mental health, for example a higher incidence of depression (Sampson et al., 2020). Nonetheless, cities still present as attractive to places live in, considering the employment opportunities, social networks, and access to facilities and services that they can provide (World Health Organization, 2010). This apparent paradox leads researchers to more closely examine the influences of different (urban) environments on health. Considering that human settlements and cities historically developed around bodies of water, research on the health impacts of blue spaces (i.e. any natural or anthropogenic body of water, such as lakes, rivers, or seashores) is highly relevant, as conclusions drawn from this line of research have the potential to increase the well-being of large populations.

Blue Spaces and Health

Research on the impact of natural environments on human health has enjoyed a surge of interest in recent years (Rickard & White, 2021; Zhang et al., 2020). Next to increasing communities' resilience to several climate change-related stressors, such as flood risk or urban heat island effects (van den Bosch & Sang, 2017), nature also has the potential to improve well-being on an individual level. Nature contact has been shown to help individuals prevent and cope with acute and chronic stress by reducing risk of cardiovascular disease, stroke, diabetes, and depression in the longer term (van den Bosch & Meyer-Lindenberg, 2019; van den Berg et al., 2015) and elevating cognitive performance and emotional states in the shorter term (McMahan & Estes, 2015; Stevenson et al., 2018), thereby reducing all-cause mortality (Rojas-Rueda et al., 2019). This evidence presents as especially vital in view of urbanization trends (United Nations, 2019) with the accompanying noise, air, and water pollution (Hou et al., 2019), as well as the cognitive strain of modern life (Kaplan & Berman, 2010).

However, most of the above noted literature is concerned only with green spaces, meaning only natural environments that prominently feature vegetation, such as grass, shrubs, trees, or other plant life. This means that aquatic environments have, in these cases, been either explicitly excluded, or simply existed as an unintentional confounding factor in the assessed environments (White et al., 2010).

In recognition of this problem, interest in the effect of blue spaces on health is steadily increasing. In a recent systematic review, Smith et al. (2021) concluded that specifically urban blue spaces show a beneficial association with all-cause mortality, obesity, general health, and self-reported mental health and well-being, with effect sizes comparable to those of green spaces. A narrative review by White et al. (2020) noted that living near the coast or an inland body of water was generally associated with better self-reported general and mental health. Furthermore, Gascon et al. (2017) concluded in their systematic review that exposure to outdoor blue spaces is associated with better mental health, well-being and greater levels of physical activity, with less consistent evidence of an association with general health, obesity and cardiovascular outcomes. While agreeing on the apparent benign influence of blue spaces, all reviews lament the small number of studies, as well as a large degree of heterogeneity in study designs, outcome measures, and exposure metrics, hindering synthesis of knowledge and comparability of blue spaces.

Benefits of Experiencing Blue Spaces: Connectedness to Nature and Restoration

One of the further notable effects of blue space contact is an increase in connectedness to nature (CN; Stehl et al., 2024; Wyles et al., 2019). CN refers to a person's psychological relationship with or emotional bond to nature (Mayer & Frantz, 2004) and has been theoretically linked to the notion of biophilia (Berto et al., 2018), which states that through evolutionary processes, humans are intrinsically motivated to seek out and prefer natural spaces (Wilson, 2007). Research on this topic indicates that visiting nature can increase CN, while higher CN is also connected to more beneficial outcomes drawn from nature contact (Berto et al., 2018; Mayer et al., 2009; Rickard & White, 2021; Stehl et al., 2024; Wyles et al., 2019). CN in the context of blue spaces has been associated with higher well-being, less mental distress, and a lower likelihood of using medication for depression (White et al., 2021). Furthermore, childhood exposure to blue spaces has been linked to higher CN, more frequent nature visits as an adult, and more pro-environmental behavior (Stehl et al., 2024). Interestingly, Wyles et al. (2019) found that nature contact (specifically including coastal environments) was associated with higher recalled CN (when CN from a visit is inquired subjectively and post-hoc) and psychological restoration (i.e. feeling relaxed or cognitively refreshed) and further noted that CN and restoration were equally likely to mediate each other in their analyses. It is reasonable to conclude that CN plays an important and complex role in several pathways between nature contact and health, intriguingly both as a cause and a result of beneficial nature experiences, and needs to be further studied.

Another notable benefit of experiencing blue spaces is psychological restoration (henceforth restoration), already described above as a feeling of relaxation, cognitive refreshment, restfulness, or recovery from mental fatigue. The concept of restoration developed within two complementary theoretical approaches: Stress Recovery Theory (SRT; Ulrich et al., 1991) and Attention Restoration Theory (ART; Kaplan, 1995). SRT postulates, from a psycho-evolutionary perspective, that contact with nature causes physiological changes concerning stress processing, parasympathetic involvement, a more positive emotional state, and thereby increased restoration (Ulrich et al., 1991). ART on the other hand, described as psycho-functionalist (Berto, 2014), states that inherent qualities of nature (such as movement patterns of rustling leaves or rolling waves) can capture involuntary attention without requiring much cognitive processing power, therefore allowing a proposed cognitive resource needed for directed attention to recharge (Kaplan, 1995). This, coupled with the notion that modern life places a great demand on directed attention to stay focused on important tasks (Kaplan & Berman, 2010) and the assumption that nature can create a sense of being away and provide opportunities for recreation, should lead to increased restoration though nature contact. Indeed, in a meta-analysis on the effects of nature exposure on restoration quantified by objective measures, Stevenson et al. (2018) found improved performance in the domains of working memory, attentional control, and cognitive flexibility, while also noting considerable heterogeneity in utilized protocols and outcome measures. Furthermore, blue spaces specifically have also been shown to have a positive association with recalled restoration (when restoration from a visit is inquired subjectively and post-hoc; Wyles et al., 2019). Additionally, more natural coastal environments (e.g., no beach amenities, not in towns) are judged as more restorative (Hooyberg et al., 2022). Present literature suggests that nature can provide resources and opportunities to help mentally cope with the stressors of modern and urban life (Hou et al., 2019; Kaplan & Berman, 2010), but research on the restorative effects of blue spaces specifically is still scarce.

Different Blue Space Types, Different Capacities

To date, blue space research has mostly focused on aquatic environments in general or specifically coastal environments, while inland or freshwater blue spaces (lakes, rivers, etc.) have received much less attention, despite their vital role in urban landscapes or landlocked areas (McDougall et al., 2020). Different blue space types can vary greatly in their physical and hydrological properties, thereby offering different opportunities for recreation and usage (Mavoa et al., 2019). It is therefore likely that different types of blue spaces will also vary in their capacity to benefit health and well-being (McDougall et al., 2020). So far, positive health effects of living in proximity to higher quality canals (Tieges et al., 2020) and lakes (Pearson et al., 2019) have been recorded in ecological studies, but individual-level research has rarely been conducted.

In an attempt to remedy this, McDougall et al. (2022) investigated the relationships between proximity and exposure to lakes, rivers, or canals and health and well-being in a Scottish sample. They found that frequently visiting rivers, canals and marine environments was associated with better mental well-being, while general health was only improved by visiting green spaces. Additionally, two hours of contact with canals or the sea per month was associated with improved well-being.

Knowledge Gaps on Blue Space Types and Quality

Despite recent efforts, research on differences between blue space types is still lacking and several key knowledge gaps remain. For example, as the body of literature specifically investigating freshwater blue spaces is still small, a consistent way of classifying different spaces has yet to be established. Reflecting on the current issue of great heterogeneity of approaches in general blue space literature (Gascon et al., 2017; Smith et al., 2021; White et al., 2020), existing research has called for a multidisciplinary approach leading to clearly defined blue space categories (McDougall et al., 2020).

Furthermore, research on blue space differences has often failed to consider blue space quality as an important variable with the potential of affecting how a blue space is used and how it facilitates health benefits (McDougall et al., 2020). This appears as an especially significant oversight in a line of research specifically acknowledging and investigating the differences of blue space typologies, as quality alone can impact how a natural environment is used and experienced (Akpinar, 2016), particularly in aquatic environments (Pitt, 2018; Wyles et al., 2016). A difference in blue space quality can, therefore, be similarly or even more impactful than a difference in blue space type alone, for example by increasing restoration or connectedness to nature (Berto et al., 2018; Wyles et al., 2019). Assessing blue space environmental quality often involves examining accessibility, safety, water quality, or cleanliness (Mishra et al., 2020). Notably, characteristics technically outside of water, such as appropriate facilities (e.g., footpaths, toilets), are also important to consider, as the salutogenic properties of water can also be accessed from surrounding land by simply being in the vicinity (de Bell et al., 2017; Elliott et al., 2018).

Present Study

The present study aims to utilize a large and representative dataset to investigate different blue space types, their quality, and their association with recalled restoration and recalled CN, while controlling for relevant covariates. Thereby, the goal of this work is to address the above outlined gaps in the literature regarding the lack of insights on different freshwater blue spaces including a quality assessment.

To answer the call for a multidisciplinary approach leading to clearly defined blue space categories (McDougall et al., 2020), hydrological/limnological definitions were applied to group different blue spaces into (1) lentic ecosystems ("standing water environment types"), (2) lotic ecosystems ("flowing water environment types"), and (3) marine ecosystems ("marine environment types"). Lentic ecosystems are defined as very slowly flowing or stagnant freshwater bodies with relatively little water exchange (e.g., lakes, ponds, wetlands; Meena et al., 2018), lotic ecosystems are defined as freshwater bodies with a considerable flow (e.g., rivers, streams, canals, waterfalls; Friberg, 2014), lastly, marine ecosystems are defined as water bodies directly associated with the sea and contain considerable salt-water levels (e.g., coasts, beaches, estuaries, lagoons; Ramesh et al., 2015).

Hypotheses

The first hypothesis assumes that previous findings on the adverse impact of bad blue space quality (e.g., Wyles et al., 2016) will also translate into the positive, as has been demonstrated before in green spaces (e.g., Akpinar, 2016). Furthermore, the second and third hypotheses are primarily based on the theoretical notion within ART (Kaplan, 1995), that natural movement patterns (more prevalent in flowing water and marine environments) are particularly restorative. Therefore, building on the above outlined literature and open questions, I formulate the following hypotheses (Figure 1):

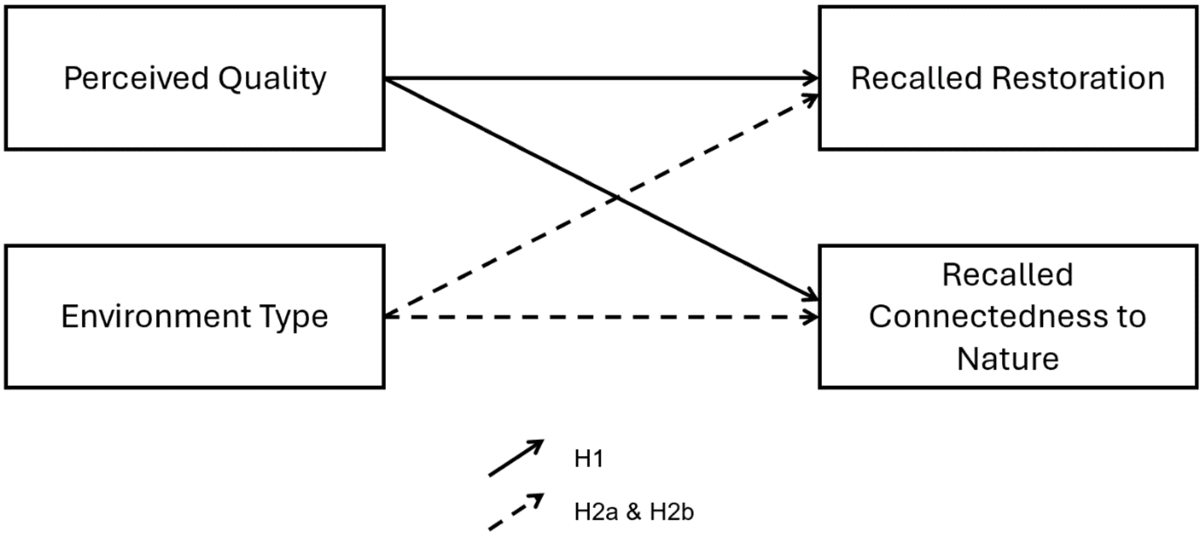
H1) Blue spaces with higher perceived quality are associated with greater recalled restoration and recalled CN.

H2a) Flowing water environments are associated with higher recalled restoration and recalled CN than standing water environments.

H2b) Marine environments are associated with higher recalled restoration and recalled CN than standing water environments.

Figure 1

Model Figure



Method

Sample

The present project is based on data from the BlueHealth International Survey, which investigated wellbeing and public health impacts of blue spaces and associated infrastructure with the aim of providing information to policymakers on how to maximise health benefits associated with blue spaces (Elliott & White, 2020). For this survey, representative samples in 15 European countries and four countries or regions outside of Europe completed an online questionnaire. Approximately 1000 people were surveyed per country/region, typically stratified by geographic region, gender, and age group. The survey was distributed by YouGov (a UK-based market research company) in four seasonal waves across a year, starting in June 2017. An exception to this is Austria, where the survey was only administered in September 2020 due to the timing of severe Covid-19 restrictions. The total sample size of the international survey was N = 21352.

Procedure

Participants were first informed about the aim of the survey (to find out how people use outdoor spaces, specifically blue spaces, internationally), then provided consent and could withdraw at any time without consequences. The survey consisted of seven modules, the first four being about subjective well-being, frequencies of visits to different natural environments, general perceptions of neighbourhood natural environments, and details on the most recent visit to a blue space, respectively. This was followed by a contingent behaviour experiment about the effects of bathing water signage (in European regions) or other region-specific items (in non-European regions). Finally, there were modules on general health and demographic data (Elliott & White, 2020).

Measures

The majority of measures relevant for this study are found in the fourth module about the most recent blue space visit of the last four weeks. Participants could select the type of blue space environment which they most recently visited from a list of 17 (e.g., a harbour, a marsh, an ornamental water feature, a public pool, a lake, or an urban river). Quality of the visited environment was assessed using five items, four of which could be answered on seven-point Likert type scales from *strongly disagree* [1] to *strongly agree* [7]. These items inquired whether the participant felt safe, there was enough wildlife, the area was free from litter, and there were appropriate facilities (e.g., bathrooms, footpaths). For the fifth quality item, perceived water quality could be rated in line with the EU bathing water quality classification, from *poor* [1] to *excellent* [4] (European Environment Agency, 2023). Furthermore, a perceived feeling of restoration during the visit was assessed with a seven-point scale using the item “I was able to rest and recover my ability to focus in that blue space”. This was based on a well-used single item measure of perceived restorativeness (e.g., Nordh et al., 2009). Whether participants felt connected to nature during the visit was assessed with the item “I felt part of nature”, also on a seven-point scale. Moreover, the main activity of the visit could be selected from a list of 30 (e.g., walking, swimming, cycling, watersports, sunbathing, eating and drinking). Many of the above-mentioned items were derived from the Monitor of Engagement with the Natural Environment survey (Natural England, 2019).

Additionally, demographic measures included sex (female/male), age (in five groups between 18 and 60+), education (in four groups between no primary education and higher education/university degree), household income (coded in deciles), and whether participants lived in a rural or urban area (based on population density).

Data Preparation

Initial data preparation was handled through IBM SPSS Statistics (Version 29) and consequent analyses were conducted using R (Version 4.4.1), primarily using the package “lme4” (Bates et al., 2015). Participants who did not report having visited a blue space in the last four weeks were excluded from analysis. Next, the 17 different environments were grouped into lentic/standing water, lotic/flowing water, and marine environment types in line with hydrological definitions (Friberg, 2014; Meena et al., 2018; Ramesh et al., 2015) to facilitate comparable results (McDougall et al., 2020). One environment named “Small water bodies (e.g. streams and ponds)” could not be assigned to an environment type and was therefore excluded from analysis.

Furthermore, the five measures of perceived environmental quality were added into one overall quality indicator (perceived water quality was recoded from a 1-to-4 to a 1-to-7 scale for equal weight across measures), then the total quality score was grand mean centered. Subsequently, different main activities were grouped into three separate activity types: active land-based (e.g., walking, running, biking), passive land-based (e.g., sunbathing, reading, eating/drinking) and water-based (e.g., swimming, boating, watersports). Participants who stated the main activity of their visit as “other” were excluded, as they could not be assigned to any activity type. Moreover, household income was recoded from deciles into quintiles to enhance interpretability of the results (with “prefer not to answer” as an additional dummy category given relatively higher numbers who replied this way).

Notably, reliable population density data was not available for the Austrian subset of data. This, coupled with the circumstance that only the capital city Vienna shows high population density, whereas other cities are comparatively small and spread out, led to analyses of the Austrian subset resorting to comparing Vienna to all other Austrian regions, instead of applying an urban/rural divide (an approach similar to Fian et al., 2023).

Analysis

To account for the nesting of participants' data in their respective countries of residence, linear mixed effect models were used to analyse data from all 19 countries and regions. In line with discussions on best practices regarding linear mixed effects models (Barr et al., 2013; Meteyard & Davies, 2020), a maximal random effects structure appropriate to the experimental design was developed in a stepwise approach using maximum likelihood, separately for each dependent variable (recalled restoration and recalled CN). Consecutive improvement of model fit was tested for via likelihood ratio tests. Prior to the main analysis, the need for a multilevel approach was confirmed by comparing the fit of a fixed-intercept-only model to that of a variable-intercept-only model (Field et al., 2012). Subsequently, the first step consisted of a baseline model with a fixed intercept and only fixed effects for the main predictors (environment type and perceived quality). Step two added fixed effects for the remaining visit- and individual-level covariates. Next, step three allowed intercepts to vary by country. Finally, step four added a random effect for environment type, allowing slopes to vary per environment in each country.

Results

Descriptives

After excluding all cases missing relevant data, a sample of N = 14393 remained for further analysis. Visitors to different types of blue space environments showed different patterns in socio-demographic and visit covariates (Table 1). For example, water-based activities were most prevalent in standing water environments (32% versus 8.5% flowing, 16.5% marine). Standing water environments were also mostly visited by the youngest age group (23.2% versus 22.9 flowing, 16.6% marine), while the reverse order is true for the oldest age group, which most often visited marine environments (26.8% versus 24% flowing, 21.2% standing). Furthermore, urban dwellers comprised the majority of visitors to flowing (61.2% versus 38.8% rural) and marine (66.6% versus 33.4% rural), but not standing water environments (46.7% versus 53.3% rural). No substantial collinearity was detected in the covariates (see appendix, Table A1).

Table 1

Bivariate Relationships between Categorical/Continuous Study Variables and Visited Environment Type

		Standing Environment		Flowing Environment		Marine Environment	
Variable	Category	n	%	n	%	n	%
Main Activity Type	Land-based Active	1713	47.5	3337	68.6	3272	55.2
($\chi^2(4) = 889.99$, $p < .001$)	Land-based Passive	740	20.5	1112	22.9	1673	28.3
	Water-based	1155	32.0	413	8.5	978	16.5
Sex	Male	1800	49.9	2527	52.0	2899	48.9
($\chi^2(2) = 10$, $p = .007$)	Female	1808	50.1	2335	48.0	3024	51.1
Age Group	Age 18-29	838	23.2	1114	22.9	986	16.6
($\chi^2(8) = 119.23$, $p < .001$)	Age 30-39	734	20.3	909	18.7	1075	18.1
	Age 40-49	644	17.8	835	17.2	1173	19.8
	Age 50-59	626	17.4	838	17.2	1102	18.6
	Age 60+	766	21.2	1166	24.0	1587	26.8
Household Income	Lowest Quintile	485	13.4	784	16.1	812	13.7
($\chi^2(10) = 37.69$, $p < .001$)	Second Quintile	490	13.6	695	14.3	861	14.5
	Third Quintile	573	15.9	573	16.4	919	15.5
	Fourth Quintile	653	18.1	653	17.2	1022	17.3
	Highest Quitile	869	24.1	869	21.5	1498	25.3
	Prefer Not to Answer	538	14.9	538	14.5	811	13.7
Education	Did not Complete Primary Education	30	0.8	24	0.5	24	0.4
($\chi^2(6) = 282.08$, $p < .001$)	Completed Primary Education	539	14.9	580	11.9	332	5.6
	Completed Secondary Education	1409	39.1	1872	38.5	2258	38.1
	Completed higher Education	1630	45.2	2386	49.1	3309	55.9
Region	Rural	1923	53.3	1885	38.8	1981	33.4
($\chi^2(2) = 373.96$, $p < .001$)	Urban	1685	46.7	2977	61.2	3942	66.6
Country	Australia	112	3.1	155	3.2	406	6.9
($\chi^2(36) = 3142.6$, $p < .001$)	Austria	814	22.6	736	15.1	94	1.6
	Bulgaria	174	4.8	432	8.9	203	3.4
	California	168	4.7	125	2.6	333	5.6
	Canada	202	5.6	208	4.3	174	2.9
	Czech Republic	200	5.5	356	7.3	53	0.9
	Estonia	186	5.2	220	4.5	223	3.8
	Finland	300	8.3	167	3.4	279	4.7
	France	123	3.4	280	5.8	266	4.5
	Germany	209	5.8	264	5.4	73	1.2
	Greece	55	1.5	82	1.7	691	11.7
	Hong Kong	120	3.3	124	2.6	484	8.2
	Ireland	114	3.2	295	6.1	362	6.1
	Italy	117	3.2	231	4.8	473	8.0
	Netherlands	150	4.2	268	5.5	198	3.3
	Portugal	83	2.3	203	4.2	443	7.5
	Spain	152	4.2	276	5.7	450	7.6
	Sweden	215	6.0	150	3.1	328	5.5
	United Kingdom	114	3.2	290	6.0	387	6.5

Continuous study variables

	Standing Environment		Flowing Environment		Marine Environment	
Variable	Mean	SD	Mean	SD	Mean	SD
Subjective Quality Rating (F (2, 14390) = 236.7, $p < .001$)	25.73	4.93	23.36	5.48	24.97	5.16

Linear Mixed Effects Models

The use of linear mixed effects models was first justified by inspecting the change of model fit between a fixed-intercept-only model and a variable-intercept-only model for each outcome variable (Field et al., 2012). For recalled restoration, modelling the variability of intercepts by country significantly improved model fit, $\chi^2(1) = 350.63$, $p < .001$. A similar result was observed for recalled CN, $\chi^2(1) = 587.50$, $p < .001$.

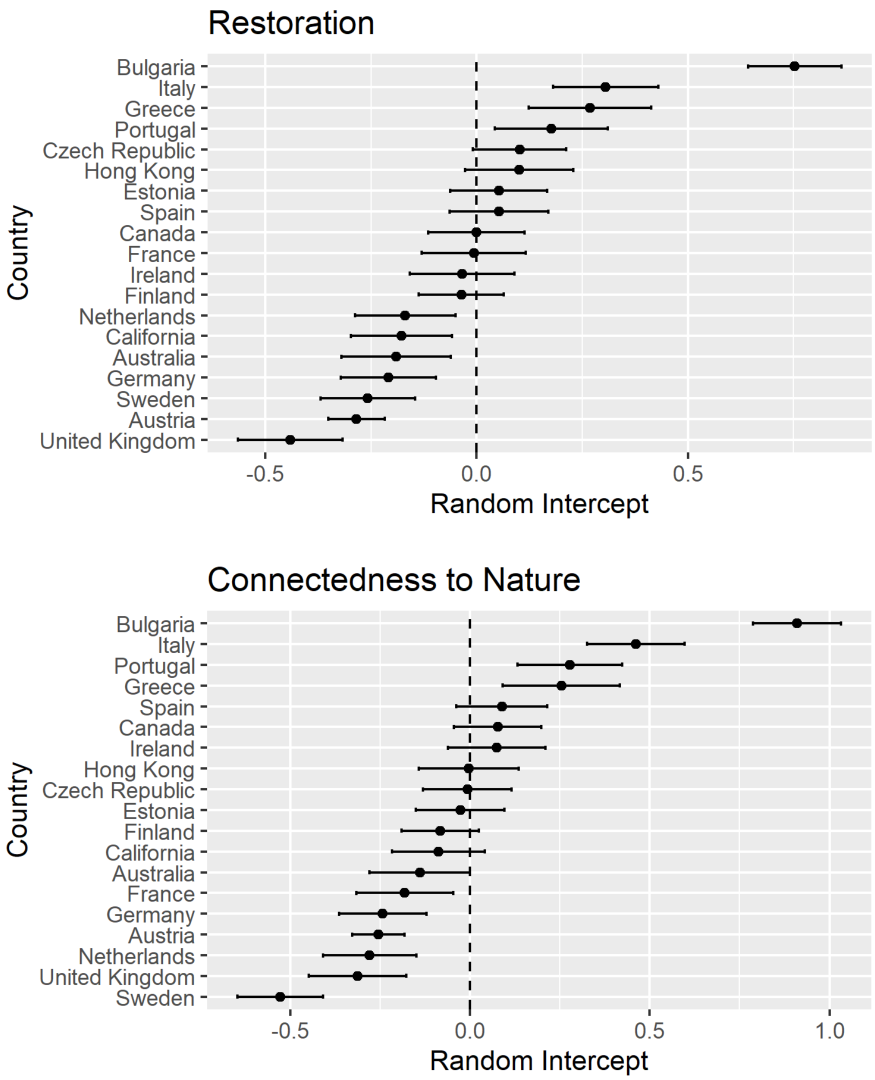
Model Development

Linear mixed effects models were developed stepwise, using Likelihood-ratio tests to compare each model's fit to that of its predecessor. After the baseline model only predicted recalled restoration from visited environment type and perceived quality, the second model additionally included visit- and individual-level covariates with fixed effects for main activity type, age, sex, education, household income and urban/rural area of residence, which resulted in a significantly better fit, $\chi^2(16) = 186.27$, $p < .001$. The third model allowed intercepts to vary across countries, which highlighted that the relationship between environment type, perceived quality, and recalled restoration showed significant variance in intercepts across countries, standard deviation (*SD*) = 0.27 [95% confidence interval (*CI*): 0.19, 0.37], $\chi^2(1) = 705.48$, p < .001 (Figure 2). The fourth model added a random effect for environment type, allowing the slope of different environments to vary across countries, which further improved model fit, $\chi^2(5) = 11.96$, $p = .035$.

Concerning recalled CN, models were developed in a similar fashion. Adding covariates in the second model again significantly increased model fit, $\chi^2(16) = 186.57$, $p < .001$. The third model once more described significant variability of intercepts across countries, *SD* = 0.33 [0.24, 0.46], $\chi^2(1) = 992.18$, $p < .001$. Lastly, the fourth model, taking into account random slopes of environments per country, also improved model fit compared to the preceding model, $\chi^2(5) = 19.67$, $p = .001$.

Figure 2

Caterpillar-Plots of Random Intercept Effects



Recalled Restoration and Connectedness to Nature as a Function of Blue Space Type and Quality

Table 2 presents the final (fourth iteration) linear mixed models for recalled restoration and recalled CN, including non-standardised estimate values (*b*), *SD*s and 95% *CI*s. Notably, the intercepts show that visits to standing water environments (the reference category for environment type) with average quality are already associated with relatively high recalled restoration (*b* = 5.17 [*CI*: 4.90, 5.43]) and CN (*b* = 4.97 [4.65,5.28]) scores on a 7-point scale. However, compared to standing water environments, marine environments had a significantly stronger positive relationship with recalled restoration (*b* = 0.124 [0.056,

Table 2

Final Linear Mixed Models on Recalled Restoration and Recalled Connectedness to Nature.

Predictor	Rec. Restoration			Rec. Connectedness to Nature		
	b	*SD*	95% *CI*	*b*	*SD*	95% *CI*
(Intercept)	5.165***	0.079	5.010, 5.319	4.965***	0.09	4.789, 5.140
Environment Type (ref = Standing Environment)						
Flowing Environment	0.029	0.030	-0.029, 0.088	0.114**	0.037	0.042, 0.186
Marine Environment	0.124***	0.035	0.056, 0.192	0.112**	0.041	0.033, 0.191
Subjective Quality Rating						
Quality (centered)	0.118***	0.002	0.114, 0.121	0.122***	0.002	0.118, 0.126
Main Activity Type (ref = Land-based Active)						
Land-based Passive	0.054*	0.023	0.009, 0.100	-0.083***	0.024	-0.130, -0.036
Water-based	0.151***	0.027	0.099, 0.204	-0.042	0.028	-0.097, 0.012
Sex (ref = Male)						
Female	0.144***	0.019	0.107, 0.181	0.175***	0.020	0.137, 0.214
Age Group (ref = Age 18-29)						
Age 30-39	0.040	0.030	-0.019, 0.099	0.120***	0.031	0.058, 0.182
Age 40-49	0.098**	0.031	0.038, 0.158	0.186***	0.032	0.124, 0.248
Age 50-59	0.145***	0.031	0.085, 0.205	0.212***	0.032	0.149, 0.274
Age 60+	0.035	0.029	-0.021, 0.092	0.246***	0.030	0.188, 0.305
Household Income (ref = Lowest Quintile)						
Second Quintile	-0.010	0.035	-0.079, 0.059	-0.031	0.037	-0.103, 0.040
Third Quintile	-0.051	0.034	-0.118, 0.017	-0.058	0.036	-0.128, 0.012
Fourth Quintile	-0.005	0.034	-0.072, 0.062	-0.059	0.035	-0.129, 0.010
Highest Quitile	-0.033	0.034	-0.099, 0.033	-0.154***	0.035	-0.223, -0.085
Prefer Not to Answer	-0.064	0.035	-0.133, 0.005	-0.122***	0.037	-0.194, -0.050

Education (ref = Completed Primary Education)						
Did not Complete Primary Education	-0.339**	0.131	-0.596, -0.082	-0.084	0.136	-0.351, 0.183
Completed Secondary Education	-0.048	0.036	-0.118, 0.022	-0.014	0.037	-0.087, 0.058
Completed higher Education	-0.104**	0.036	-0.174, -0.033	-0.034	0.038	-0.107, 0.040
Region (ref = Rural)						
Urban	-0.006	0.021	-0.047, 0.035	-0.081***	0.022	-0.123, -0.038

Random Effects

	Rec. Restoration		Rec. Connectedness to Nature	
	σ^2	*ICC*	σ^2	*ICC*
(Intercept)	0.071		0.101	
Flowing Environment	0.003	-0.578	0.01	0.060
Marine Environment	0.009	0.257	0.016	0.092
Residual	1.254		1.351	
AIC / BIC	44243.71 / 44448.22		45333.63 / 45538.14	
Observations	14393		14393	

Note. The final models include fixed effects for main predictors, main activity type, and demographics, as well as random effects for intercept and environment type by country. Abbreviations: *SD* = standard deviation; *CI* = confidence interval; *ICC* = intraclass correlation; *AIC* = Akaike information criterion; *BIC* = bayesian information criterion.

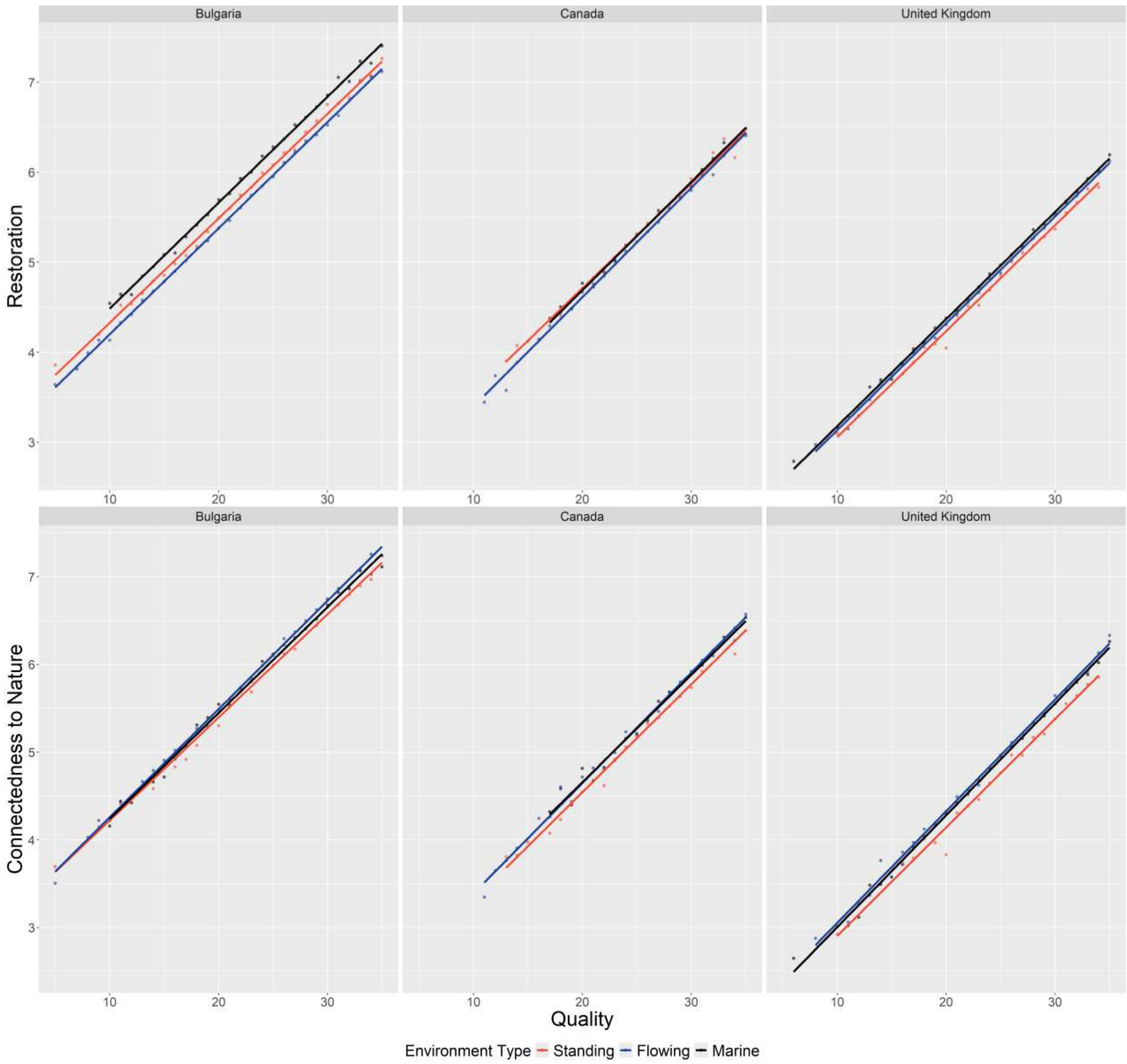
*p<.05, **p<.01, ***p<.001

0.192]), while flowing water environments only showed a small and insignificant association (*b*= 0.029 [-0.029, 0.088]). Regarding recalled CN, both flowing (b = 0.114 [0.042, 0.186]) and marine environments (*b* = 0.122 [0.118, 0.126]) showed a significant positive effect of similar size, compared to standing water environments. Furthermore, subjective quality of the visited environment had a strong and highly significant positive effect on both recalled restoration (*b* = 0.118 [0.114, 0.121]) and recalled CN (*b* = 0.122 [0.118, 0.126]).

Regarding random effects, inspecting the different intercepts per country reveals an interesting pattern, as well as similarities between intercepts for recalled restoration and CN (Figure 2). For example, Bulgaria showed the highest intercept for both outcomes, followed by Italy, Portugal and Greece, while the lowest intercepts were found in countries such as Sweden, Austria, and the United Kingdom. Figure 3 illustrates differing slopes depending on

Figure 3

Mean Predicted Values per Quality Rating of Recalled Restoration and Connectedness to Nature with Regression Lines Indicating Random Slopes per Environment Type in Three Selected Countries



environment type, with predicted values of both outcomes as a function of perceived environmental quality in three countries (selected for their high, medium, and low intercept). All environment types in every country greatly benefitted from an increase in quality, although the strength of this effect varied. In Bulgaria for example, marine environments consistently appeared most restorative across all levels of quality, while the increase of CN was strongest in flowing environments when quality improved. For random slopes results for all countries, see appendix, Figures A1 and A2.

Effects of Visit- and individual-Level Covariates

Both passive land-based (b = 0.054 [0.009, 0.100]) and water-based activities (b = 0.151 [0.099, 0.204]) were associated with higher recalled restoration compared to active land-based activities. The opposite seems to be the case regarding recalled CN, where passive land-based activities show a highly significant negative effect (b = -0.083 [-0.130, 0.036]), while water-based activities show no significant difference to active land-based activities. Females showed both significantly higher recalled restoration (b = 0.144 [0.107, 0.181]) and CN (b = 0.175 [0.137, 0.214]) compared to males. Furthermore, only middle age groups showed a significantly stronger positive effect on recalled restoration compared to the youngest age group. Recalled CN, however, was significantly higher in all groups older than the reference category, with the effect increasing with age. Household income did not make a significant difference to recalled restoration across all categories, while only the highest quintile income, as well as “prefer not to answer” categories showed a significantly negative difference in recalled CN compared to the lowest quintile income group. Lastly, people living in urban regions reported significantly lower recalled CN compared to rural regions. There was no difference between urban and rural dwellers in recalled restoration.

Discussion

For this study, a large, international, and representative sample (N = 14393) was analyzed to discern the relationship between the type of a visited blue space, the perceived quality of that space, and the restoration and connectedness to nature that people gained from their visit. From the gathered results, interesting insights can be drawn on the main predictors, as well as the included sociodemographic covariates.

The current findings show that an increase in blue space quality was positively associated with increases in both recalled restoration and recalled CN. Further, while visits to standing water were associated with relatively high levels of recalled connectedness and restoration, both marine and flowing water environments were associated with significantly higher recalled CN. This is consistent with the theory of biophilia, which proposes that humans are evolutionarily inclined to seek out and thrive in well-suited natural spaces (Wilson, 2007). Furthermore, only marine environments were linked to significantly higher recalled restoration. This is largely supported by ART (Kaplan, 1995), which indicates that moving water should capture attention and increase restoration more easily than relatively calm standing water. The missing association between flowing water environments and higher restoration could be explained by the superior ability of marine environments to provide a sense of being away through expansive ocean views.

To summarize, two out of three hypotheses were fully supported, while the remaining hypothesis on the effect of flowing water environments was only accurate for recalled CN, but not restoration. Overall, this strengthens existing assumptions on the impact of quality on the effects of nature (Akpinar, 2016; Berto et al., 2018) and specifically blue spaces (Pitt, 2018; Wyles et al., 2016, 2019). These results additionally reduce the knowledge gap on freshwater blue spaces (McDougall et al., 2020) by noting considerable benefits but also differences between categories, thereby reflecting the current state of the literature (McDougall et al., 2022) while offering further insight.

Regarding activity types, both passive activities on land and water activities were associated with higher recalled restoration, which could be explained by the more likely appreciative nature of the specific activities within these categories (e.g., eating/drinking, boating, paddling, sunbathing). Recalled CN, however, was highest for the active land-based activities category, possibly caused by experiencing multiple natural scenes in succession through walking, running, and cycling, or by having a more immersive experience, like walking barefoot (Rickard & White, 2021).

Finally, effects of sociodemographic variables were also in line with what is known in the literature: Females reported higher recalled restoration and CN than males (Wyles et al., 2019). Recalled CN increased with age and was lowest in urban populations and the highest income group, which could in both cases be explained by the number and frequency of nature exposures (Cox et al., 2018). Moreover, recalled restoration was highest in middle age groups (age 40-59) compared to the youngest age group, which should, according to the literature, have extended to also include the oldest age group (Cervinka et al., 2012; Luck et al., 2011). Lastly, recalled restoration was lowest in the two extremes of education categories (no primary education, completed higher education) with no notable effect on recalled CN. This finding is especially hard to accurately interpret, as this area is relatively understudied, and no recognizable pattern emerged. Restorative potential is possibly less salient for people less educated about nature, while highly educated people could perhaps have problems developing a sense of being away, as they are known to be generally more concerned for the environment (Gifford & Nilsson, 2014).

Limitations

Although the present study has considerable strengths, especially in its large and representative sample, some limitations must be noted. Many of these limitations stem from the characteristics of the BlueHealth International Survey. Recalled restoration and recalled CN are both based on a single item measure, which limits reliability, even when those single item measures are widely used. Furthermore, asking participants to recall their most recent blue space visits, while providing valuable real-world data otherwise not achievable through experimental methods, also introduces a considerable probability of certain biases distorting participants’ reports of their actual experiences. Lastly, it is important to highlight that the cross-sectional nature of the data does not allow for causal interpretations. Nevertheless, the relationships discovered in this study offer great insight and are of interest to future research as well as policy on natural spaces and benefits they can provide.

Implications

Conclusions drawn from this study shed more light on the relationship between different blue spaces and well-being, as well as which characteristics affect said relationships. When considering the development or maintenance of a blue space, the present findings can be used as a guide on how to maximize the effect on mental health and nature connectedness of the surrounding population.

Considering cumulative effects (effects from an individual extended to a population, and from one visit to a life of visits), this research also supports several United Nations

Sustainable Development Goals. For instance, goal 3.4 aims to reduce premature mortality from non-communicable diseases, goal 6.6 demands greater protection and restoration of water-related ecosystems, goals 11.4 and 11.7 propose to protect the world's cultural and natural heritage and provide universal access to green spaces, and goal 14.2 appeals to more sustainably manage and protect marine and coastal ecosystems (United Nations, 2023). The present findings directly substantiate and expand existing knowledge on the importance of blue spaces not just in their own right, but also as a catalyst of health in modern life, thereby moving our society closer to these goals.

Still, further research is needed to more firmly establish causality, clarify pathways between freshwater spaces and health, and test in-situ applications of these findings.

Conclusion

This study analyzed a large, international, and representative sample from 19 countries utilizing linear mixed effects models and found that different blue spaces offer different capacities of benefitting health, while the quality of a given blue space is also critical throughout. Both recalled restoration and connectedness to nature were improved in higher quality spaces. Visits to flowing water environments were associated with higher restoration, while those to marine environments were associated with both greater restoration and connectedness to nature. Overall, these findings contribute to an understudied topic in blue space research, highlighting the importance of high-quality blue spaces, as well as highlighting strengths of different blue space types.

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Appendix

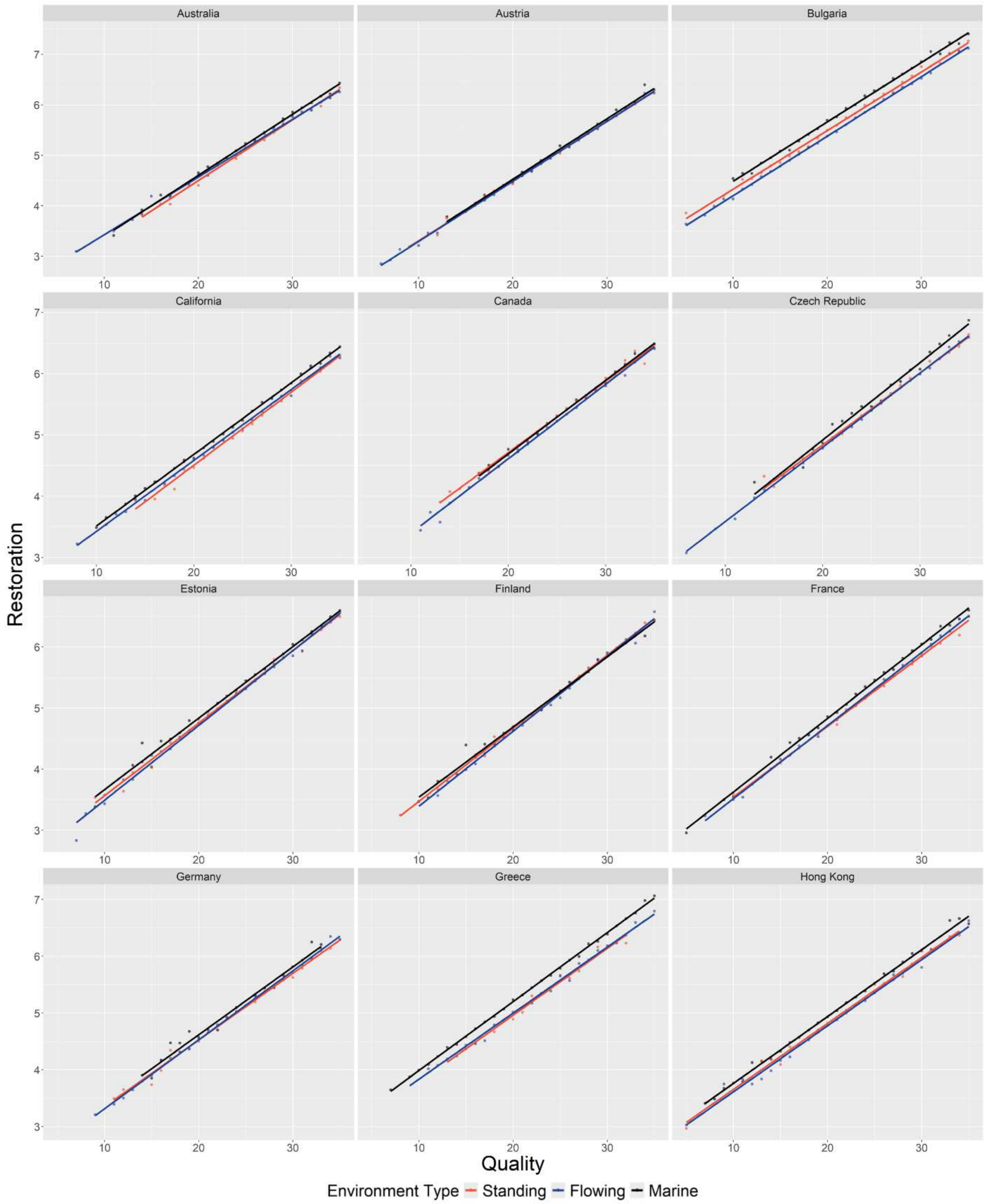
Table A1

Multicollinearity Diagnostics

Variable	VIF	T (1/VIF)
Standing Environment (reference category)	---	---
Flowing Environment	1.6	0.63
Marine Environment	1.53	0.65
Quality	1.06	0.94
Land-based Active (reference category)	---	---
Land-based Passive	1.1	0.91
Water-based	1.14	0.88
Male (reference category)	---	---
Female	1.02	0.98
Age 18-29 (reference category)	---	---
Age 30-39	1.6	0.63
Age 40-49	1.6	0.63
Age 50-59	1.58	0.63
Age 60+	1.71	0.59
Lowest Quintile (reference category)	---	---
Second Quintile	1.7	0.59
Third Quintile	1.79	0.56
Fourth Quintile	1.91	0.52
Highest Quitile	2.1	0.48
Prefer Not to Answer	1.73	0.58
Education	1.06	0.94
Completed Primary Education (reference category)	---	---
Completed Secondary Education	3.35	0.3
Completed higher Education	3.47	0.29
Rural (reference category)	---	---
Urban	1.02	0.98

Figure A1

Mean Predicted Values per Quality Rating of Recalled Restoration with Regression Lines Indicating Random Slopes per Environment Type in all Countries



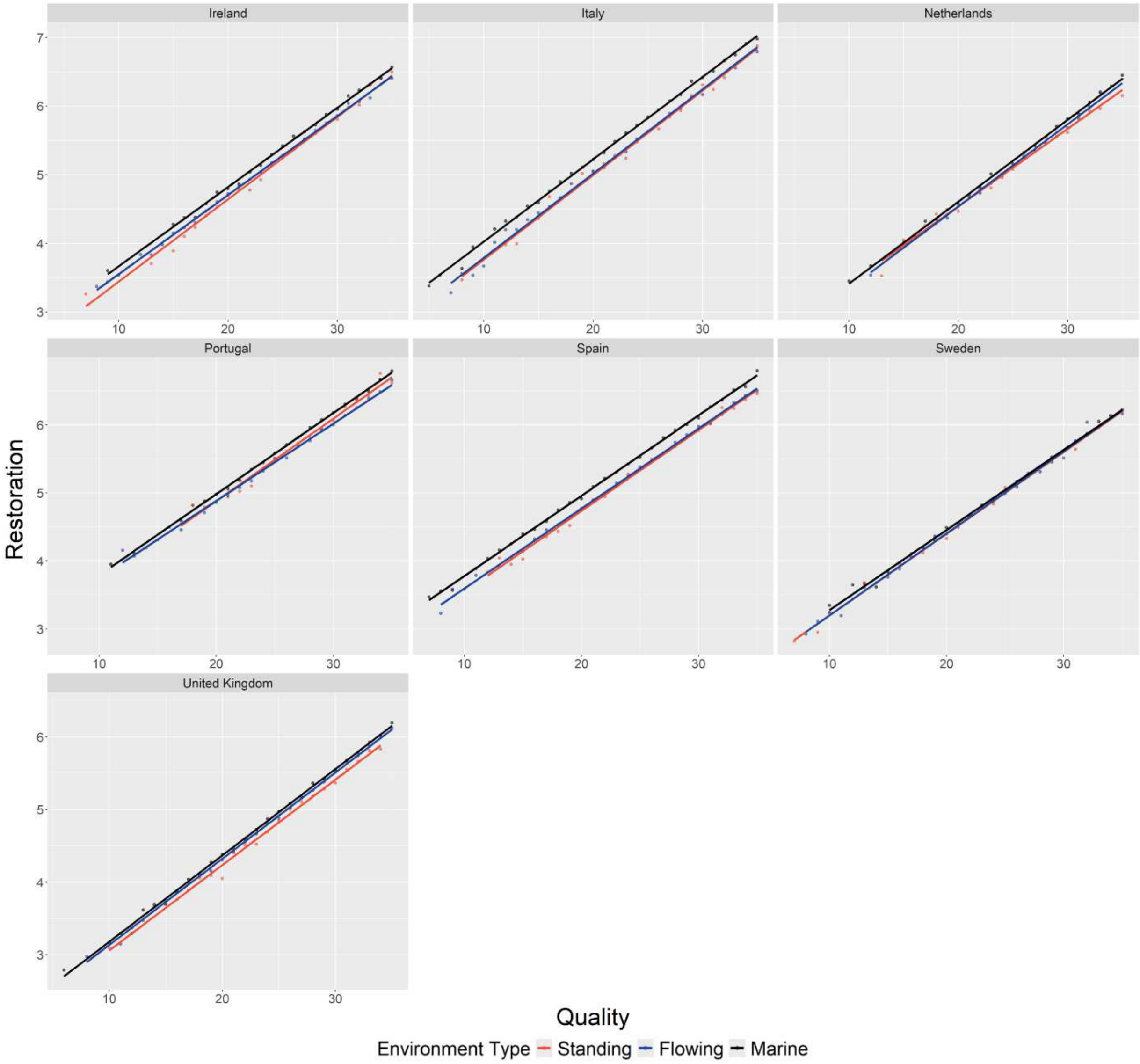
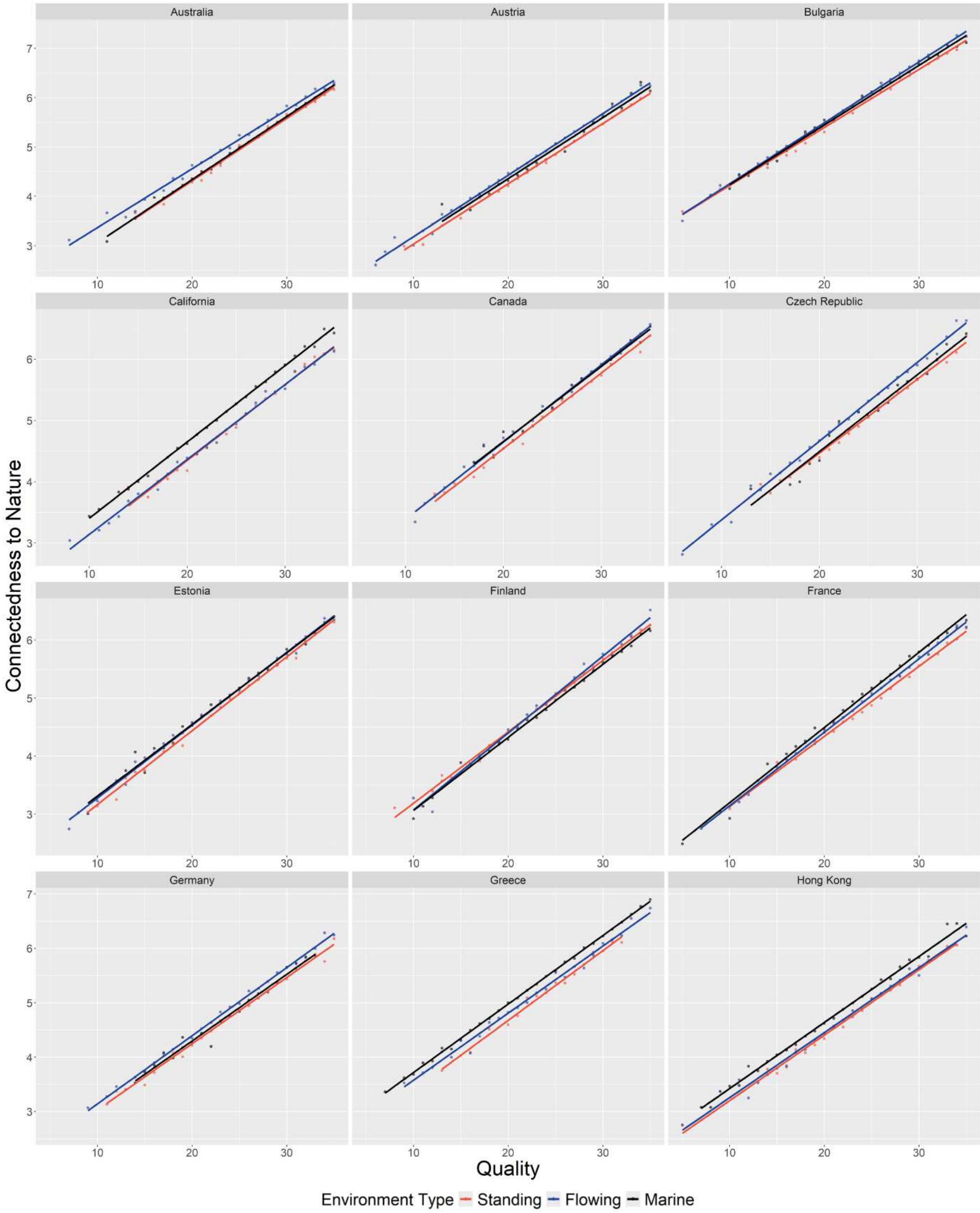
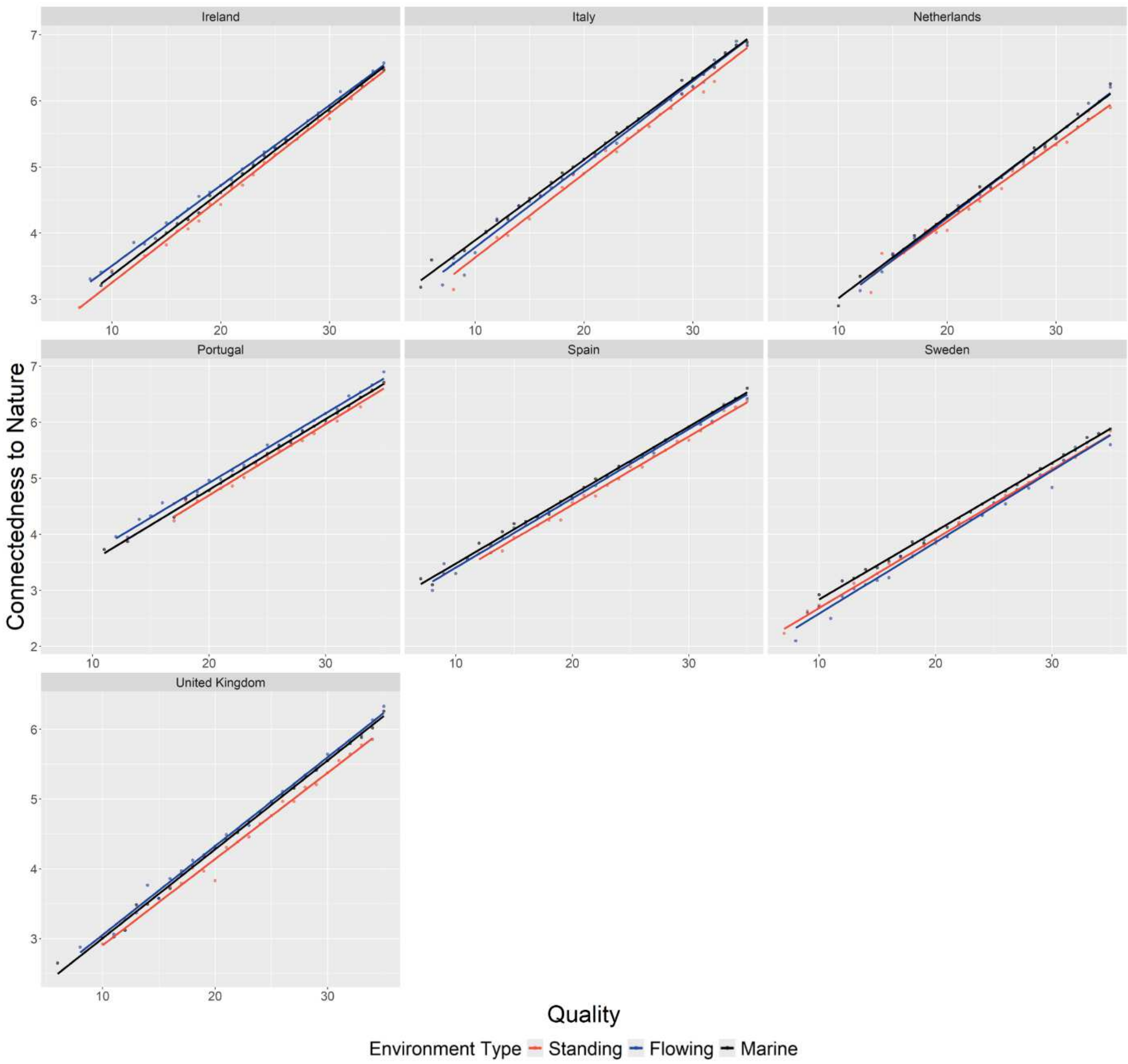

Ireland
Italy
Netherlands
Portugal
Spain
Sweden
United Kingdom
Restoration
Quality
Environment Type
Standing
Flowing
Marine

Figure A2

Mean Predicted Values per Quality Rating of Recalled Connectedness to Nature with Regression Lines Indicating Random Slopes per Environment Type in all Countries





Ireland
Italy
Netherlands
Portugal
Spain
Sweden
United Kingdom
Connectedness to Nature
Quality
Environment Type
Standing
Flowing
Marine