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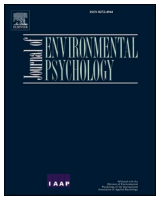

From childhood blue space exposure to adult environmentalism: The role of nature connectedness and nature contact

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ABSTRACT

Nature contact in childhood is associated with pro-environmental behaviours (PEB) later in life. While previous literature focused on nature contact in general, the current work specifically explored childhood blue space exposure (coasts, rivers, lakes etc.) and potential mechanisms underlying any relationship with PEBs in adulthood. Cross-sectional data from an Austrian sample representative on age, gender, and region (N = 2,370) were used to test a serial-parallel mediation model linking recalled childhood blue space exposure to self-reported adult PEBs via, first, nature connectedness and, second, recent visits to green and blue spaces. Results supported significant serial mediation, with recalled childhood blue space exposure linked to nature connectedness in adulthood, which was in turn associated with more frequent recent visits to green and blue spaces, which in turn predicted PEB. Significant direct and indirect effects were observed, while controlling for known individual- and area-level covariates. Findings highlight the potential importance of childhood blue space exposure as well as life-long nature contact for improving nature connectedness and PEB and add to calls for protecting and maintaining natural water bodies and to improve their safety, as spending time around them in childhood may play a role in fostering PEB and ultimately improving planetary health.

1. Introduction

1.1. Overview

As the consequences of environmental issues such as climate change and the biodiversity crisis become more tangible, fundamental changes in people's behaviour are needed to preserve a planet that is habitable for humans (IPCC, 2023). As individual-level pro-environmental behaviours (PEBs; e.g. recycling, energy conservation, using non-motorised transport) can have a substantial impact on reducing carbon emissions (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009), it is crucial to identify their underlying correlates. There is growing evidence that nature contact is associated with PEB (Alcock, White, Pahl, Duarte-Davidson, & Fleming, 2020; DeVille et al., 2021) and that reduced nature contact may impair support for environmental causes (Soga & Gaston, 2016). However, research suggests that many people around the world are having less and less contact with the nature world. Although the data are mixed, a recent review identified trends for both decreasing direct nature contact, reflected in demographic shifts from rural to urban living and a reduction of urban woodlands, and decreasing vicarious nature contact such as declines in the presence of nature in children's cultural products such as movies and books (Cazalis, Loreau, & Barragan-Jason, 2023). The phenomenon of decreasing nature contact in children in each subsequent generation has been labelled

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"extinction of experience" (Pyle, 1993; Louv, 2008, although see Novotný, Zimová, Mazouchová, & Šorgo, 2021) and becomes concerning when considering the links between nature contact in childhood and connection with and care for nature later in life (Cleary, Fielding, Murray, & Roiko, 2020; Evans, Otto, & Kaiser, 2018; van Heezik, Freeman, Falloon, Buttery, & Heyzer, 2021).

Some studies have already suggested life-course models connecting experiences with nature in childhood to adult environmentalism. For example, childhood nature contact has been associated with adult nature contact (Rosa, Profice, & Collado, 2018), nature connectedness (van Heel, van den Born, & Aarts, 2023) and PEB (Wells & Lekies, 2006). To date, most of these studies have focused on childhood exposure to either nature in general, or green natural spaces (e.g. parks, gardens etc.). The current research extends this line of work to blue space environments (e.g. rivers, lakes and coastlines). As with green spaces, a growing body of work has linked exposure to blue spaces to a range of positive health and well-being outcomes (Gascon, Zijlema, Vert, White, & Nieuwenhuijsen, 2017; Geiger et al., 2023; Giorgiou et al., 2021; White et al., 2020), including previous childhood blue space exposure (Díaz-Martínez et al., 2023; Vitale et al., 2022). Of more direct relevance here are studies suggesting that: a) exposure to and connectedness with blue spaces in adulthood can also promote and encourage PEBs, especially those PEBs that have a direct impact on these locations such as beach cleans (Wyles, Pahl, Holland, & Thompson, 2017) and reducing single use plastics (Nuojua, Pahl, & Thompson, 2022); and that b) greater awareness of blue spaces and linked threats (e.g. marine litter) in childhood is also associated with PEBs at this age (George, Murray, & Christian, 2023; Hartley, Thompson, & Pahl, 2015, Hartley et al., 2018). What remains lacking is clear evidence linking blue space exposure in childhood to adult pro-environmentalism. Moreover, most studies linking blue space exposure to PEB, in both adults (Nuojua et al., 2022; Wyles et al., 2017) and children (George et al., 2023; Hartley et al., 2015, Hartley et al., 2018) focused on coastal settings and little is known about inland blue space settings such as rivers and lakes.

To address these gaps in our knowledge, the current research explored associations between recalled childhood blue space exposure and adult self-reported PEB in the landlocked country of Austria. Data were drawn from a cross-sectional survey of the adult population, representative on age, gender and region, and included items on not only recalled childhood exposure and current PEBs but also adult nature connectedness and recent visits to blue and green spaces which allowed us to explore potential pathways, or mechanisms, linking childhood experiences to adult behaviours. Before outlining the specific hypotheses, we briefly summarise some of the key literature behind our predictions.

1.2. Childhood nature, pro-environmentalism, and the relevance of blue spaces

Wells and Lekies (2006) were among the first to propose that engagement with nature in childhood can put people on a "path towards environmentalism". Subsequent studies suggested that childhood nature experiences predict environmental concern (Gifford & Nilsson, 2014) and comfort with, interest in, and emotional connection to nature among adults (Soga & Gaston, 2016). Natural environments children are exposed to may create a sense of "prior familiarity" in specific settings, influencing adult preferences for natural landscapes as well as impacting the benefits derived from exposure to those landscapes (Cleary, Fielding, Bell, Murray, & Roiko, 2017; Meidenbauer et al., 2019).

Although much of this research has focused on green spaces and nature in general, there is also evidence that children are regularly exposed to natural blue spaces. Of course, it is not always possible to view blue and green natural spaces as entirely separate from each other, because especially inland water bodies, such as lakes and rivers, are often surrounded by greenery. However, blue spaces can be distinguished from green spaces regarding their unique sensory qualities (e.g., light reflections, wave motion, sounds, etc., Völker & Kistemann, 2015), and the opportunities they offer for other kinds of leisure activities for children and adults that are not possible around green spaces (e.g., swimming, fishing, watersports, Elliott et al., 2018). Much of the world's population, including children, live near waterbodies such as the coast (Cohen, Small, Mellinger, Gallup, & Sachs, 1997), lakes (Kummu, De Moel, Ward, & Varis, 2011), and rivers (Wüstemann et al., 2017), suggesting regular exposure is at least possible. This was supported by a recent study of blue space visits across 18 countries which found that around 27% of all visits included children and that "playing with children" was the primary activity on around 5% of those visits (Garrett et al., 2023).

As well as awareness of environmental issues arising from the children's own perceptions of degradation of the blue spaces they visit (De Veer et al., 2022), children living near and attending schools by significant water bodies, such as the coast, may also engage in educational programmes discussing blue space specific environmental issues such as marine litter (Hartley et al., 2015; Oturai, Pahl, & Syberg, 2022). These educational programmes are often linked to children's direct local experiences (Hartley et al., 2018) and may help reinforce a bond in children's minds between places that are important to them, e.g. because they associate them with intrinsically rewarding activities and quality time with friends and family (Ashbullby, Pahl, Webley, & White, 2013) and the need to engage in PEBs to protect them. However, to date there has been little research to investigate whether contact with such blue spaces in early life is linked to (sustained) pro-environmentalism in later life.

1.3. Nature connectedness and nature contact as underlying mechanisms

Research suggests that the relationship between nature contact and PEB can be explained via the cultivation of factors such as place attachment (Lawrence, 2012), biocentric values (Larson, Whiting, & Green, 2011) and, most relevant for the current study, connection to nature (Otto & Pensini, 2017). Nature connectedness refers to a person's subjectively perceived closeness to and relationship with the natural world. This connection can be viewed as both a psychological trait that remains relatively stable across situations and over time (Nisbet, Zelenski, & Murphy, 2009), as well as a psychological state that an individual enters during a specific encounter with the natural world (Wyles et al., 2019). Whether viewed as a state or a trait, nature connectedness is a complex construct, comprising cognitive, affective, experiential, and personality factors (Lumber, Richardson, & Sheffield, 2017).

A recent meta-analysis identified frequent contact with nature as a strong predictor for feelings of nature connectedness (Sheffield, Butler, & Richardson, 2022). There is also evidence that nature connectedness is facilitated in people who live close to the coast (Alcock et al., 2020) and who experienced greater nature exposure in childhood (Asah, Bengston, Westphal, & Gowan, 2018; Cleary et al., 2020). Further, meta-analyses found consistent evidence of nature connectedness as a key predictor for PEB (Mackay & Schmitt, 2019; Whitburn, Linklater, & Abrahamse, 2020). The combination of the findings makes nature connectedness a promising mediator between recalled childhood blue space exposure and adult PEB. Rosa et al. (2018) proposed a model of this relationship – additionally including current recreational nature contact – and showed that the association between recalled childhood nature exposure and adult PEB seems to be at least partially mediated by the level of nature connectedness.

Studies investigating the relationship between adult nature contact

and adult PEB have shown meaningful associations between them (Hartig, Kaiser, & Strumse, 2007; Weinstein et al., 2015). This association has even been shown in controlled experimental settings, where participants were only indirectly exposed to nature on a screen (Arendt & Matthes, 2016; Zelenski, Dopko, & Capaldi, 2015). Another consistent finding across cross-sectional studies was an association between early and current nature contact, which may be due to habit formation and lifestyle preferences established in early childhood (Pensini, Horn, & Caltabiano, 2016; Rosa et al., 2018). In conclusion, the research base suggests that nature connectedness as well as current contact with nature might be important explanatory factors between childhood nature exposure and adult PEB.

1.4. The current study

To investigate these issues further, the current study proposed a path model of the relationship between recalled childhood blue space exposure and adult PEB, with nature connectedness and recent blue space visits as serial mediators. The approach was inspired by the one used by Vitale et al. (2022) that explored the relationships between recalled childhood blue space exposure and subjective well-being in adulthood. Key differences here include a focus on PEB as the dependent variable instead of well-being, connectedness to nature as the first mediator instead of intrinsic motivation to visit nature as in the earlier paper, and a sample drawn from the landlocked country of Austria resulting in a focus on non-marine, inland waters. Nevertheless, like the Vitale et al. (2022) paper we also included recent visits to green as well as blue spaces at the second mediation stage to account for the general tendency to visit any nature setting in adulthood. The model is also similar to that investigated by Rosa et al. (2018), although here we focus exclusively on recalled blue space exposure in childhood and again differentiate between recent green and blue space contact, whereas Rosa et al. (2018) examined childhood experiences and current recreational contact with nature in general.

Our approach is visualized in Fig. 1. Hypothesis 1 (H1) predicted a positive relationship between recalled blue space exposure in childhood and self-reported PEB in adulthood. H2 posited that this relationship would be, at least partially, mediated by nature connectedness in adulthood, such that greater recalled childhood blue space exposure would be associated with greater connectedness to nature in adulthood, which in turn would be associated with more self-reported PEBs. H3 suggests that, in turn, the relationship between nature connectedness and PEBs would itself be, at least partially, mediated by the tendency to spend time in nature, operationalised here in terms of recent visits to both blue (H3a) and green (H3b) spaces. In short, we predicted that higher recalled blue space exposure as a child would be associated with higher nature connectedness in adulthood, which in turn would be linked to more nature (especially blue space) visits, and that spending more time in nature would ultimately result in more PEBs.

2. Methods

2.1. Sample

The data for this study were collected as an extension to the BlueHealth International Survey (BIS), conducted as part of the European Union funded BlueHealth project on blue spaces and health (Grellier et al., 2017; White et al., 2020). As part of that project, data were collected in 18 countries by the international polling company YouGov using online survey panels. The data for Austria were collected during October 2020 after the original round of data collection had been completed in 2018, by the same polling company using the same sampling protocol. No formal power analysis was conducted, but a sample of 2,500 participants was deemed sufficient by the polling company to provide a dataset representative on age, gender and region for the entire adult population of Austria (Final N = 2,514; Fian et al., 2023). Data were collected in accordance with relevant guidelines and regulations, and informed consent was obtained from all participants. Ethical approval for the BIS was granted by the University of Exeter Medical School's Research Ethics Committee (Ref: Aug16/B/099). Of note, at the time of data collection for the Austrian cohort there had been some partial lifting of COVID-19 restrictions, but many people were still working from home and commuting and leisure travel using cars and public transport was still relatively reduced compared to pre-pandemic norms. Omitting participants with missing data on the key variables reduced the sample by 5.7%, leaving an analytic sample of N = 2,370 participants (50% females), aged 18–89 years. Full demographic information of the sample is provided in Supplementary Table S1.

2.2. Measures

2.2.1. Pro-environmental behaviour (PEB)

Self-reported PEB was measured with 12 binary yes/no items (no N/A option), adapted from the special Eurobarometer survey on the attitudes of Europeans towards the environment (Eurobarometer, 2020). The original Eurobarometer survey consisted of 14 items and asked about engagement in the behaviours in the last six months, whereas this survey: a) asked about having performed the respective behaviour in the last four weeks, to be consistent with the timeframe for nature visits (and other health related items); and b) left out two items that were directly affected by the pandemic given the time of data collection ("used your car less by avoiding unnecessary trips", "working from home"). Supplementary Table S2 displays exact wordings of the questions and comparisons of agreement rates between the Eurobarometer survey and

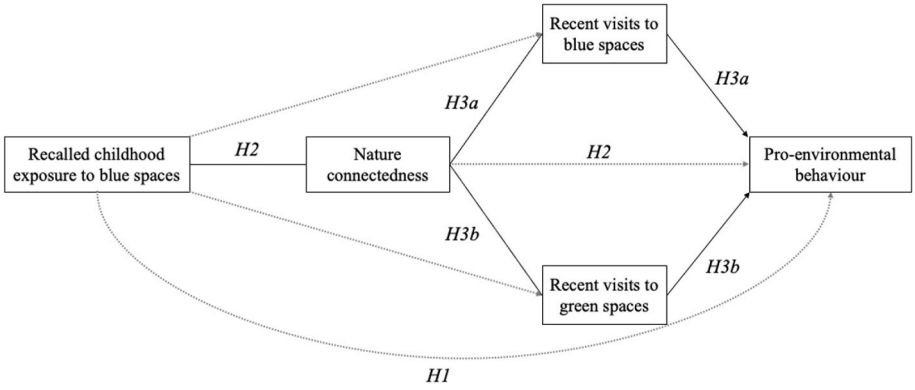

Fig. 1. Proposed conceptual model linking recalled childhood blue space exposure to adult PEB via the serial-parallel mediators nature connectedness and recent visits to green and blue spaces (solid lines = indirect paths, dotted lines = direct paths).

this survey. We note here that the self-reported rates of engaging in these PEBs in the last four weeks were often substantially higher than the self-reported engagement in the last six months, both for the EU as a whole and particularly for Austria, based on the most recent Eurobarometer data (collected in 2019). We return to why this might be and what implications it might have had for results in the discussion section. The twelve behaviours were summed to form a metric of PEBs in general (potential scores ranged from 0 to 12; $\alpha = 0.67$).

2.2.2. Recalled childhood blue space exposure

At the start of the survey blue spaces were defined as follows: "Blue spaces include water and could be inland areas like lakes, canals, rivers, fountains and pools; urban coastal areas such as seaside resorts, harbours, ports and piers; or other coastal areas such as beaches, cliffs and headlands. However, these spaces do not include: (a) indoor locations, (b) places which you visit as part of your job, or (c) private locations such as your own garden, land, pond, or swimming pool." For childhood exposure in particular, respondents were asked to recall relevant experiences made between the ages 0 and 16: (1) "As a child, there was easily accessible blue space near my home(s)." (2) "As a child, my parents/guardians were comfortable with me playing in and around blue spaces." (3) "As a child, I often visited blue spaces." Responses were on a 7-point scale, ranging from −3 = "strongly disagree" to 3 = "strongly agree", with a separate "don't know" option which was coded as missing. The internal consistency of the scale was high with $\alpha = 0.82$. Thus, the three variables were averaged into a single predictor variable.

2.2.3. Nature connectedness

To measure Nature Connectedness, the Inclusion of Nature in Self scale by Schultz (2001) was used. It consists of a single item and the instruction "Please select the picture that best describes your relationship with the natural environment. How interconnected are you with nature? ('Self' = you; 'Nature' = the environment)". The scale ranges from 1 = "least connected" to 7 = "most connected" with a separate "don't know" option which was coded as missing. Nature connectedness was handled as a continuous measure to support comparisons with the limited set of studies focused on childhood nature connectedness and adult PEB (Evans et al., 2018; Rosa et al., 2018; Wells & Lekies, 2006). Of note, given the visual similarity of our model to that tested by Vitale et al. (2022) we wanted to check whether we really were exploring a different mediating process than pursued in that paper, i.e. intrinsic motivation as measured by the item "I find visiting green and blue spaces enjoyable and fun", which was also measured in the current dataset. Supporting our aim, the correlation between nature connectedness and intrinsic motivation was just $r = 0.01$, $p = .801$, suggesting the mediating processes in our two models are conceptually different. (Of note the correlation between the two variables across the 18 countries used by Vitale et al. (2022) was also low $r = 0.05$, suggesting this is not merely an artefact of our Austrian sample).

2.2.4. Recent visits to blue and green natural spaces

Participants were presented with a list of 29 natural environments, 12 green spaces and 17 blue spaces (see Vitale et al. (2022) for full list and images) and indicated how often they had visited those environments in the last four weeks (spanning September and October 2020). There were four response options for each location ("not at all in the last four weeks", "once or twice in the last four weeks", "once a week", "several times a week"). Based on prior work using the 18-country BIS dataset (White et al., 2021), it was conservatively estimated that these response options equated to 0, 2, 4 and 8 visits respectively over the last four weeks. The frequencies of all green space visit types and all blue space visit types were summed separately so that an approximate number of visits to each general setting could be used in mediation analysis. To address the skewness caused by a few participants with very high visit frequencies, both variables were capped at 56 visits, which indicated a maximum of visiting green and blue spaces twice a day in the last month (feasible, say, for dog owners walking their pets twice a day). 1.2% of participants for green space visits and 1.6% of participants for blue space visits were limited by this capping.

Recent visits to both blue and green spaces were included in this study to assess the potential distinct contributions of both types of nature visits (de Bell, Graham, Jarvis, & White, 2017; Gascon et al., 2017; Völker & Kistemann, 2015), although the primary interest was in exploring the association between contact with blue spaces (in childhood and adulthood) and adult PEB. Additionally, the more general measure of nature connectedness has no specific focus on being connected to blue or green spaces. Thus, it is appropriate to explore how a general connection to the natural world is associated with visit frequencies to both types of natural environments.

2.2.5. Control variables

At a preliminary stage we also adjusted for socio-demographic covariates that have been shown to be associated with PEB, nature connectedness, and nature contact in previous research (Martin et al., 2020): Gender (male, female = ref); age groups (18–29 years = ref; 30–39 years, 40–49 years, 50–59 years, ≥60 years); self-identified belonging to an ethnic minority (yes = ref., no); highest level of educational achievement (secondary school or lower = ref; a-levels; degree); employment status (in paid employment, in education, retired, homemakers; other, not working/unemployed = ref); disposable household income quintiles (lowest quintile = ref); relationship status (single/separated/divorced/widowed = ref; married/cohabiting); number of adults in household (1 = ref; 2, ≥3); number of children in household (0 = ref, 1, ≥2); dog ownership (yes, no = ref); car ownership (yes, no = ref); and also Austrian region (Vienna = ref; Lower Austria, Upper Austria, Burgenland; Carinthia, Styria; Salzburg, Tyrol, Vorarlberg).

Further, nature-related covariates concerning participants' current residential exposure to green and blue spaces were also included. Home geolocations were entered by participants using a Google Maps API with coordinates rounded to three decimal degrees on the latitude and longitude scales to preserve anonymity. For blue spaces, data available from the European Catchments and Rivers Network System (ECRINS) database (European Environment Agency, 2012) were used to assign Euclidean (crow-flies) distances in kilometres from the home geolocation to the nearest river and lake separately. Given skew, we created simply binary variables based on distances to the nearest lake and to the nearest river (More than 1 km = ref., less than 1 km). For green spaces, the Normalised Difference Vegetation Index (NDVI) was used with data taken from MODIS Terra satellite imagery (https://modis.gsfc.nasa.gov/). The NDVI is a measure of the amount of photosynthesizing green plants within a certain radius around participants' homes. NDVI values for the amount of vegetation within a 1 km radius around participants' homes were used and grouped into quartiles, with the lowest NDVI quartile indicating the least amount of vegetation around participants' homes (lowest quartile = ref.). For the analyses, all covariates mentioned were used as categorical variables and were included in the models using dummy coding.

2.3. Analytic approach

All analyses were conducted using SPSS Version 27.0 and the PROCESS-Macro by Hayes (2017). PROCESS uses an ordinary least-squares (OLS) path analytical framework to test for both direct and indirect effects and provides several mediation models to explore. For this analysis, model 81 (serial-parallel mediation) was chosen to test the proposed model shown in Fig. 1. All indirect effects were subjected to follow-up bootstrap analyses with 5,000 bootstrap samples to determine if the indirect effects are different from zero by providing 95% confidence intervals around those effects.

Before the main analysis, Pearson correlations were used to estimate the hypothesised directions and possible association strength between

predictor, mediator, and outcome variables. Preliminary regression analyses for PEB were then conducted, starting with a covariates-only model, and adding predictor and mediator variables one at a time (see Supplementary Table S3 for full results of preliminary regressions with all considered covariates). The results helped to justify the main mediation analysis, by confirming that by successively adding the mediator variables the effect of the predictor variable was reduced, while also considering relevant covariates. Finally, the hypothesised mediation analysis was conducted with PROCESS. The residuals for recent blue and green space visits were allowed to covary since there was no underlying reason to suppose they are causally related. Following standard practice when discussing the paths in models such as these, we use the terms direct, indirect and total "effects", aware that because our data are cross-sectional, causality cannot be conclusively demonstrated.

3. Results

3.1. Descriptive statistics

Means, standard deviations, and correlations of the key variables are presented in Table 1. In partial support of all hypotheses, all variables correlated positively and significantly with each other. As might be expected, the correlation between recent visits to blue and green spaces was particularly strong. Table 1 also shows that Austrians visited green spaces on average considerably more frequently than blue spaces within the last month, which may in part be explained by a lack of coastline and travel restriction for holiday destinations abroad (e.g. Croatia and Italy) during Autumn 2020. Table 1 also shows that the means for both nature connectedness and PEB lie above their scale mid points (3.5 for nature connectedness, 6.5 for PEB), suggesting our sample was moderately connected to nature, on average, and also relatively pro-environmental in their behaviour.

3.2. Main analysis

Table 2 shows the full mediation model with direct effects of key variables and covariates on PEB (including both unstandardized coefficients to aid interpretation of effects relative to response scales, and standardised coefficient for comparison across predictors). Table 3 additionally displays the indirect path coefficients for our key variables, which are crucial for hypothesis testing. Because PROCESS only provides confidence intervals for standardized indirect effects, we report only these here.

Supporting H1, the total effect model of recalled childhood blue space exposure on adult PEB, (with no mediators added) was significant with $R^2 = 0.07$, $F(13, 2356) = 14.48$, $p < .001$, and a positive association between recalled childhood blue space exposure and PEB of $b = 0.29$ [*95% CIs* = 0.23; 0.36] was observed. The direct effect model, where all mediators were considered, was also significant ($R^2 = 0.15$, $F(16, 2353) = 26.68$, $p < .001$), with the association between recalled childhood blue space exposure and PEB dropping to $b = 0.20$ [*95% CIs* = 0.14; 0.26]. These results support partial mediation since only a part of the original variance appears to be accounted for by connectedness and nature visits. The models accounted for 4%, 5%, and 11% of the variance in nature connectedness, recent blue space and green space visits, respectively, as well as 15% of the variation in PEB.

Crucially, for the serial mediation hypotheses (H2 and H3), there were small but significant indirect pathways from recalled childhood blue space exposure to PEB through nature connectedness (H2, $b = 0.05$ [*95% CIs* = 0.03; 0.06]), through nature connectedness and recent visits to blue spaces (H3a, $b = 0.002$ [*95% CIs* < 0.001; 0.004]) and through nature connectedness and recent visits to green spaces (H3b, $b = 0.008$ [*95% CIs* 0.005; 0.012]). A non-hypothesised path, indicating only partial serial mediation was also significant for the green space visits mediator only (i.e. not through connectedness, $b = 0.03$ [*95% CIs* = 0.02; 0.04]). The indirect effect through blue space visits only was the only non-significant indirect effect ($b = 0.0072$ [*95% CIs* = −0.0002; 0.0156]). To sum up, the model supports all proposed hypotheses and yields findings that are in line with those from the literature reviewed.

While there were meaningful direct associations between recalled childhood and adult blue space exposure, and adult blue space exposure and PEB, the results of the indirect effects suggest that adult visits to blue spaces alone do not sufficiently explain a significant part of the relationship between recalled childhood blue space exposure and adult PEB. For adult blue space exposure to become a significant mediator of this relationship, nature connectedness needs to be incorporated into the assumed causal chain.

3.3. Covariates

Women reported, on average, more PEBs than men. Male participants did, however, report significantly more greenspace visits than females. Employed Austrians and those who did not want to state their occupation performed significantly fewer PEBs than did unemployed Austrians. Compared to unemployed participants, employed and retired participants had higher nature connectedness on the one hand, but indicated fewer nature visits, especially to blue spaces, on the other. Participants in the highest income quintile and those who did not want to make a statement about their income performed significantly fewer PEBs in comparison to participants in the lowest quintile. Additionally, participants from higher income groups indicated spending more time in nature than did participants from the lowest income group. However, this finding was not linear across income quintiles and only participants from the income quintiles 3 and 5 stated significantly more visits to blue and green spaces than the reference group. Finally, participants from households with more than one adult performed significantly more PEBs and participants from households with three or more people visited green spaces substantially more often than single households (see Table 2 for exact values).

Table 1
Descriptive statistics for and correlations between key variables.

	M	*Mdn*	Percentiles		*SD*	Correlation coefficients			
			25th	75th		1	2	3	4
1. Recalled childhood blue space exposure[a]	0.87	1.00	0.00	2.00	1.56	–			
2. Nature connectedness[b]	4.56	5.00	3.00	6.00	1.66	.15***	–		
3. Recent visits to blue spaces[c]	10.10	6.00	2.00	14.00	11.75	.12***	.15***	–	
4. Recent visits to green spaces[c]	16.86	14.00	6.00	25.00	13.49	.17***	.25***	.57***	–
5. Pro-environmental behaviour[d]	7.23	7.00	6.00	9.00	2.45	.18***	.26***	.17***	.24***

Note: *M* = mean, *Mdn* = Median, *SD* = standard deviation, ***$p < .001$.
[a] Childhood exposure scores ran from −3 (strongly disagree) to +3 (strongly agree).
[b] Scores for nature connectedness ran from two circles with no intersection (least connected = 1) to two circles completely overlapping (most connected = 7).
[c] Number of recent visits in the last four weeks capped at a maximum of 56.
[d] PEB measured with 12 binary items (yes/no), a higher score indicating more environmentally friendly behaviours.

Table 2
Full mediation model predicting PEB from childhood blue space exposure, nature connectedness, recent visits to blue and green spaces and relevant covariates (i.e. those that were significant in preliminary models – see Supplementary Table S3).

Predictor	Outcome: INS			Outcome: Blue Space Visits			Outcome: Green Space Visits			Outcome: PEB			Total Effect Model		
	b	*SE*	*β*	*b*	*SE*	*β*	*b*	*SE*	*β*	*b*	*SE*	*β*	*b*	*SE*	*β*
Childhood Exposure	0.16***	0.02	.15	0.72***	0.15	.10	1.11***	0.17	.13	0.20***	0.03	.13	0.29***	0.03	.19
Nature Connectedness				1.02***	0.14	.15	1.89***	0.16	.23	0.29***	0.03	.19			
Visits to Blue Spaces										0.01*	0.03	.05			
Visits to Green Spaces										0.03***	<0.01	.14			
Gender (female = ref.)	−0.15	0.07	−.04	0.93	0.49	.04	1.35*	0.54	.05	−0.65***	0.10	−.13	−0.66***	0.10	−.13
Work status (unemployed = ref.)															
Employed	0.25*	0.11	.07	−2.51**	0.76	−.11	−0.72	0.85	−.03	−0.43**	0.15	−.09	−0.34*	0.16	−.08
In education	0.03	0.17	<.01	−1.86	1.20	−.04	−0.48	1.34	−.01	0.10	0.24	.01	0.08	0.25	.01
Retired	0.52***	0.13	.12	−3.76***	0.92	−.13	−0.81	1.02	−.02	−0.32	0.18	−.05	−0.20	0.19	−.03
Other	0.08	0.17	.01	0.07	1.15	<.01	0.17	1.29	<.01	−0.56*	0.23	−.06	−0.52*	0.24	−.05
Household income (Lowest Quintile = ref.)															
Quintile 2	0.21	0.13	.04	0.23	0.91	.01	0.46	1.01	.01	0.15	0.18	.02	0.23	0.19	.03
Quintile 3	0.10	0.13	.02	2.31**	0.87	.08	1.92	0.97	.05	0.01	0.17	<.01	0.12	0.18	.02
Quintile 4	−0.03	0.13	−.01	1.60	0.91	.05	1.85	1.01	.05	0.01	0.18	<.01	0.06	0.19	.01
Quintile 5	0.06	0.13	.01	3.10***	0.93	.10	2.79**	1.03	.08	−0.49**	0.18	−.08	−0.37	0.19	−.06
No response	0.04	0.12	.01	0.32	0.87	.01	1.19	0.97	.03	−0.51**	0.17	−.08	−0.46*	0.18	−.07
Adults in household (1 = ref.)															
2 adults	0.20*	0.09.	.06	−0.87	0.64	−.04	0.41	0.72	.01	0.41**	0.13	.08	0.45***	0.13	.10
3 or more adults	0.18	0.10	.05	−0.06	0.68	<.01	3.61***	0.76	.13	0.51***	0.14	.10	0.66***	0.14	.13
Constant	4.05***			5.55***			4.21***			5.69***			7.25***		
R^2	.04			.05			.11			.15			.07		

b = unstandardized coefficients, *SE* = Standard Error, *β* = standardized coefficients. *$p < .05$, **$p < .01$, ***$p < .001$.

Table 3
Results of mediation analysis examining direct and indirect pathways linking recalled childhood blue space exposure and PEB.

Outcome	Predictor	Effects pathway	*b*	*95% CIs*	*β*
Nature connectedness $R^2 = 0.04$	Recalled childhood blue space exposure	Direct (a_1)	0.16***	0.12, 0.21	0.15
Recent visits to blue spaces $R^2 = 0.05$	Recalled childhood blue space exposure	Direct (a_2)	0.72***	0.42, 1.02	0.10
	Nature connectedness	Direct (d_1)	1.02***	0.74, 1.31	0.15
Recent visits to green spaces $R^2 = 0.11$	Recalled childhood blue space exposure	Direct (a_3)	1.11***	0.77, 1.45	0.13
	Nature connectedness	Direct (d_2)	1.89***	1.58, 2.21	0.23
PEB $R^2 = 0.15$	Recalled childhood blue space exposure	Direct (c')	0.20***	0.14, 0.26	0.13
		Indirect via nature connectedness	0.05*	0.03, 0.06	0.03
		Indirect via recent visits to blue spaces	0.007	< −0.001, 0.015	0.005
		Indirect via recent visits to green spaces	0.03*	0.02, 0.04	0.02
		Indirect via nature connectedness and recent visits to blue spaces	0.002*	<0.001, 0.004	0.001
		Indirect via nature connectedness and recent visits to green spaces	0.008*	0.005, 0.012	0.005
	Nature connectedness	Direct (b_1)	0.29***	0.23, 0.34	0.19
	Recent visits to blue spaces	Direct (b_2)	0.01*	0.001, 0.02	0.05
	Recent visits to green spaces	Direct (b_3)	0.03***	0.02, 0.03	0.14

Note: Reported were only the pathways available in the PROCESS output. † PROCESS does not provide significance levels for indirect pathways thus an indirect path is considered as significant when the estimates confidence intervals did not include zero. *b* = unstandardized coefficients, *CI* = Confidence Intervals, *β* = standardized coefficients. *$p < .05$, **$p < .01$, ***$p < .001$.

4. Discussion

Various researchers have argued that experiences with the natural world in childhood may predispose people to be more pro-environmental in later life (Evans et al., 2018; Wells & Lekies, 2006). As possible underlying mechanisms for this relationship, nature connectedness (Cleary et al., 2020; Rosa et al., 2018), and nature visits (Pensini et al., 2016; Rosa et al., 2018) in adulthood, have been proposed. Most research in this area has focused on the effects of green natural spaces or nature in general, but recent evidence suggests that living near, spending time in, and being taught about blue natural spaces can also affect children's pro-environmentalism (Hartley et al., 2015, Hartley et al., 2018), though whether this extends into adulthood, and non-marine settings has rarely been explored. Using data from a cross-sectional sample of the adult Austrian population we attempted to investigate these issues.

4.1. Key findings

Supporting predictions, the present study found a positive association between recalled blue space exposure in childhood and PEB in adulthood. This relationship held after controlling for known individual-level and area-level covariates, indicating that recalled childhood blue space exposure may be a robust predictor of adult PEB, at least in Austria. Regarding the underlying mechanisms of this relationship, we found evidence for the mediating effects of: a) greater nature connectedness; and b) more frequent visits to blue and green natural spaces in adulthood. Specifically, the model proposed a timeline where (recalled) childhood blue space exposure was associated with greater trait nature connectedness in adulthood (Soga & Gaston, 2016), which in turn

predicted recent visits to green and blue spaces in the last four weeks (Nisbet et al., 2009), which were then associated with recent PEBs over the same time period (DeVille et al., 2021). The fact that all indirect effects, including serial-mediation, were significant, provided broad support for our basic model.

Nevertheless, several direct associations were also significant suggesting alternative pathways linking childhood blue space exposure and PEBs than those proposed in the model. First, and in line with previous literature, we found positive associations between childhood blue (nature) contact and PEBs, unmediated by nature connectedness or visit frequency (path c' in Fig. 2). This could be due to factors such as childhood exposure increasing biocentric values (Larson et al., 2011) and intrinsic nature-related motivations (Vitale et al., 2022), which can in turn lead to more PEBs (Hartig, Kaiser, & Bowler, 2001), especially ones associated with personally meaningful settings (Scannell & Gifford, 2010). In the context of blue spaces these kinds of behaviours may be those that have a direct impact on aquatic environments, including inland ones (van Emmerik, Mellink, Hauk, Waldschläger, & Schreyers, 2022), such as Item 3: "Avoided single-use plastic goods other than plastic bags (e.g., plastic cutlery, cups, plates, etc.) or bought reusable plastic products" (Supplementary Table S2).

Second, extending a similar pattern in Vitale et al. (2022), who had intrinsic motivations instead of nature connectedness as the possible mediator between childhood exposure and visits, recalled childhood blue space exposure was directly associated with both blue and green space visits in adulthood unmediated by nature connectedness (paths a_2 and a_3 in Fig. 2). Having access to and visiting blue spaces as a child, and potentially having positive experiences with friends and family (Ashbullby et al., 2013) may create positive memories, feelings of familiarity and safety (Bratman, Olvera-Alvarez, & Gross, 2021), and habits that sustain into adulthood (Pensini et al., 2016; Rosa et al., 2018; Ward Thompson, Aspinall, & Montarzino, 2008) irrespective of one's attitudes and beliefs about nature *per se*. From this perspective simple positive reinforcement and well-known processes of conditioning in childhood, alongside aspects such as place identity (Lawrence, 2012), could explain adult behaviour.

Third, supporting Asah, Bengston, and Westphal (2012) nature connectedness was directly associated with PEBs unmediated by visits (path b_1 in Fig. 2). This is also consistent with earlier work which found evidence of alternative mechanisms linking nature connectedness and PEB such as environmental attitudes (Whitburn, Linklater, & Milfont, 2019), biospheric concern (Gosling & Williams, 2010), or even automatic, physiological reactions (Annerstedt van den Bosch & Depledge, 2015). Clearly, our model was only partial and subsequent work is needed to further explore a wider range of mediating factors through the development of fuller models that can account for multiple serial and parallel mediation pathways.

4.2. Secondary results

Women reported on average more PEBs than men, which is in line with prior research suggesting that women are more concerned about the environment and hold stronger pro-environmental attitudes than men (Gifford & Nilsson, 2014). Male participants reported significantly more greenspace visits than women, reflecting earlier findings that women engage less in nature-based recreation despite their usually stronger connection to nature due to worries about safety and/or less leisure time due to work, household and caring responsibilities (Boyd, White, Bell, & Burt, 2018). Employed and retired participants had higher nature connectedness on the one hand, but indicated less nature visits, especially to blue spaces, on the other, in comparison to unemployed participants. This pattern might be due to employed participants not having as much free time to spend in nature as unemployed participants, and retired participants who potentially face mobility/health issues (Boyd et al., 2018) but nonetheless can derive benefits from blue space views from home if available (Garrett, Clitherow, White, Wheeler, & Fleming, 2019). Participants in the highest income quintile and those who did not want to make a statement about their income performed significantly fewer PEBs in comparison to participants in the lowest quintile, which is consistent with previous findings (e.g. Gatersleben, Murtagh, & Abrahamse, 2014). Additionally, participants from higher income groups visited blue and green spaces more frequently than did participants from the lowest income group. Although this may be explained by poorer areas having less access to recreational natural environments in countries such as the UK (Boyd et al., 2018), in Austria inequalities of access are far less obvious (Fian et al., 2023). Rather, patterns of use of specific blue spaces seem related to income and ethnicity, with lakes in Austria visited more by people on higher incomes and urban rivers by those self-identifying as belonging to an ethnic minority (Fian et al., 2023), suggesting that future studies should consider even more specific locations than generic green and blue spaces. Finally, participants from households with more than one adult performed significantly more PEBs than single households. Evidence concerning this is scarce and ambiguous, with some studies having found no effect of household size on individual-level PEB (Huddart Kennedy, Krahn, & Krogman, 2015), while per capita environmental impacts are usually lower in larger households (e.g. Bruderer Enzler & Diekmann, 2015).

4.3. Limitations

Even though the results of this study were promising, we recognise several methodological and conceptual issues which mean caution interpreting the findings is advised. First, the cross-sectional nature of the data does not allow us to make concrete causal conclusions. For

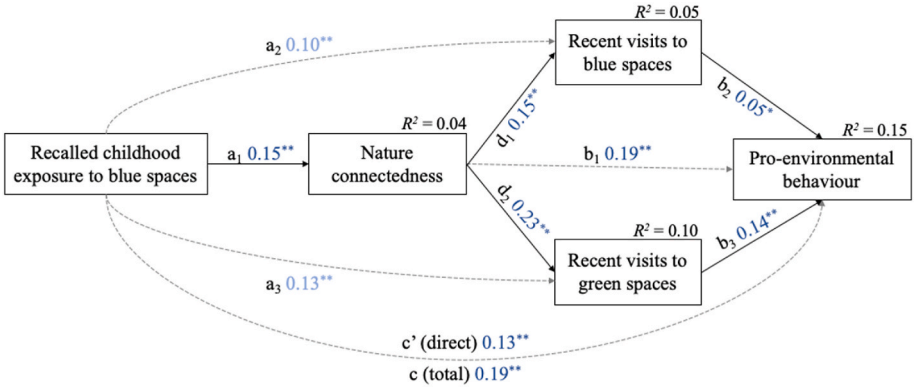

Fig. 2. Tested path model with hypothesised and additional path coefficients (here standardized for ease of comparison). Covariate paths, and covariance between the residuals of green and blue space visits, are omitted for clarity. Hypothesised paths coefficients are depicted in dark blue, additional path coefficients in light blue. $^*p \leq .05$, $^{**}p \leq .001$. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

instance, although it is logically impossible that current adult attitudes and behaviours affect childhood blue space exposure, we did not have actual data on childhood exposure and relied on recollections and memories as in previous studies on childhood nature exposure and adult outcomes (see also Rosa et al. (2018) and Wells and Lekies (2006) for a similar limitation). To the extent that current thoughts and experiences may bias recall about childhood nature contact (Chawla & Derr, 2012), this part of our model needs to be treated with caution until further longitudinal work such as that by Evans et al. (2018) can be conducted.

Second, and similarly, we also recognise that it is not at all clear whether nature connectedness influences nature visits or vice versa (Asah et al., 2012). Because the two constructs are moderately positively correlated (Mayer & Frantz, 2004; Nisbet et al., 2009), Gifford and Nilsson (2014) suggested that they may be interdependent. Here, however nature contact was defined as recent visits in the last four weeks, whereas connectedness used the trait-like Inclusion of Nature in Self measure which would widely be assumed to be relatively stable over such a short time frame. For this reason, we felt we chose the most logical model and that it was not sensible to test a reverse causality model from visits to INS using the current data. We recognise, however, that other models using other metrics, and preferably longitudinal data, may be able to explore the interdependencies more directly.

Third, we also note that self-reported PEBs were especially high in the current sample compared to previous EU and Austrian data and that this may have had some potential reverse causality effects. Specifically, the data were collected during a time (October 2020) when many people were emerging gradually from several months in COVID-19-related lockdowns and it is possible that several of the behaviours measured (e.g. “repaired a product instead of replacing it”, see Supplementary Table S2) may have been adopted out of necessity. For example, it was found that people engaged in more household and leisure related PEBs to deal with the confinements of lockdown (Ramkissoon, 2020) and there seems to be an increase in the belief of the existence and severity of the issues that arise from humans interfering with nature (Daryanto, Song, & Soopramanien, 2022). According to self-perception theory (Bem, 1972), observing oneself behaving more environmentally might then lead one to infer that one is also more connected to nature (i.e. a possible reverse causality explanation of the association between nature connectedness and PEBs). Furthermore, due to lockdown conditions there is widespread evidence that people across the world also spent more recreational time in natural spaces (Hansen, Beery, Fredman, & Wolf-Watz, 2023; Labib, Browning, Rigolon, Helbich, & James, 2022; Litleskare & Calogiuri, 2023) with levels remaining higher as the pandemic subsided (Kim, Shoji, Mameno, Kubo, & Aikoh, 2023), so the association between recent visits and PEBs may be purely associative, i.e. both occurred simultaneously due to a third factor but were causally unrelated. Thus, although we think the directions assumed in our model are reasonable, we recognise that they are not definitive.

Fourth, a further issue with collecting data during the COVID-19 pandemic, was that some social and travel restrictions were still in place, and the psychological impact of the pandemic may still have been affecting behaviour beyond the technical restrictions. Although Austria experienced a more relaxed phase during the time of data collection (October 2020), it is possible that nature visits do not represent the Austrian norm. This might be the case because many hotels, restaurants and leisure providers in the mountains and recreational areas were still closed (BMLRT, 2021). However, domestic hotel stays increased during the summer and fall of 2020 (BMLRT, 2021), so it can be assumed that more Austrians spent their summer holidays in their own country, making it likely that they were referring to Austrian nature when indicating their nature visits in the survey.

Fifth, our measure of childhood nature experiences was quite narrow only asking about recalled blue and not greenspace exposure or any details of where individuals grew up that might have allowed more objective estimates of surrounding nature access. These kinds of life-course approaches have been fruitfully used to explore cumulative exposures over many years including childhood and adolescence elsewhere (e.g. Browning et al., 2022; Pearce, Cherrie, Shortt, Deary, & Ward Thompson, 2018). However, the strong positive correlation between visits to green and blue spaces in adulthood ($r = 0.57$) suggests that children who spend time in (and whose parents are comfortable with them spending time in) blue spaces may also have spent time in green spaces when they were younger. A clearer picture of the role these different settings in childhood might have on adult connectedness to nature, visits and PEBs would require better differentiation in future work and greater efforts at understanding the locations in which they grew up. A similar argument might be made for measures of nature connectedness, which in theory might also be split into self-environment overlaps for blue and green spaces separately to explore whether connectedness to different types of environments may be different (e.g. see Yeo et al., 2020; Nuojua et al., 2022 for versions of the INS which focus on marine environments in particular).

Sixth, all the data is self-reported which may be particularly problematic for recollections of childhood, due to the length of time that has passed, and current PEBs given possible demand characteristics arising from increasing social norms to act pro-environmentally. As with much survey-based research, caution must be given to these findings until more robust measures of the constructs investigated can be obtained. Further, qualitative or mixed method approaches, like those in a recent study by van Heezik et al. (2021), could also help to address issues we were not able to explore using the purely quantitative data available to us here. For instance, these authors included both more detailed questions about participants’ childhood nature experiences than those used here and an open question allowing participants to add e.g. individual memories, activities or qualities regarding their nature experiences in childhood. Approaches like this may allow deeper insights into the environmental history of respondents, which in turn help to obtain more robust constructs, identify other important covariates or possible pathways linking childhood exposure to blue spaces with adult PEB.

Finally, although the large heterogenous sample, representative on age, gender and region, allows to make some tentative inferences about the adult population of Austria, we recognise that the pattern of results may be different in other countries and cultural and climatic contexts and different kind of natural spaces (e.g. Australia, Pensini et al., 2016).

4.4. Implications

These limitations notwithstanding, the results still suggest several practical implications. First, the findings add to the body of work recommending outdoor play and exposure to natural, and especially blue space, settings for children. We suggest that those experiences foster connection with nature, which even though they may be below conscious awareness (Schultz, Shriver, Tabanico, & Khazian, 2004), can lead to the kind of PEBs in adulthood needed to improve planetary health. Because of the potential risks associated with blue spaces, some parents are understandably concerned about their children playing around them (Pitt, 2019) and therefore keep them from doing so. But in the context of other contemporary risks (e.g., motorised traffic), appropriate supervision of recreational activities is needed anyway and safety measures around public blue spaces are suggested, in combination with communication about actual risks in natural environments versus risks in urban environments to avoid undue precaution (Ball & Ball-King, 2018). Second, to better inform landscape planning, future work needs to consider more details of the blue spaces visited in childhood and adulthood, including types of blue spaces, as well as their exact composition and qualities. This is already done in closely related areas of research, e.g. on blue spaces and well-being (Garrett et al., 2023), but currently lacks evidence for nature connectedness and PEB. Third, while research on the effects of blue spaces has largely focused on coastlines, our own data are based on a sample from landlocked Austria and thus are most relevant to inland blue spaces. We note thought that more than 50% of the global population lives within 3 km of a

freshwater body (Kummu et al., 2011), and most urban residents, in Germany for instance, live within 1 km of a river (Wüstemann, Kalisch, & Kolbe, 2017) so our findings are still potentially relevant to large sectors of the population in many countries globally. Nevertheless, further work looking at child and adult exposure to different sorts of blue space setting, inland as well as coastal, may extend the field further still (McDougall, Quilliam, Hanley, & Oliver, 2020).

4.5. Conclusion

Growing detachment from the natural world may hinder the development of nature connectedness and PEBs. We provide evidence for a positive relationship between (recalled) childhood blue space exposure and adult PEBs, which may be partly explained by adult nature connectedness and recent nature visits. These relationships were found among a large heterogenous sample in landlocked Austria, highlighting the importance of inland blue spaces (McDougall et al., 2020), compared to the more frequently studied coastal ones (White et al., 2020). If causal evidence can be established by subsequent research, the findings might play a crucial role in tackling environmental issues, as spending time around blue spaces, could improve human's connection to nature, in turn leading to increased levels of PEBs.

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Declaration of competing interest

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

CRediT authorship contribution statement

Patricia Stehl: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Mathew P. White:** Conceptualization, Funding acquisition, Methodology, Writing – review & editing. **Valeria Vitale:** Conceptualization, Writing – review & editing. **Sabine Pahl:** Funding acquisition, Writing – review & editing. **Lewis R. Elliott:** Methodology, Writing – review & editing. **Leonie Fian:** Methodology, Writing – review & editing. **Matilda van den Bosch:** Conceptualization, Writing – review & editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvp.2023.102225.

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