Landscape and Urban Planning 215 (2021) 104232

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Urban blue space renovation and local resident and visitor well-being: A case study from Plymouth, UK

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HIGHLIGHTS

- A small-scale co-created 'acupuncture' intervention was realised at an urban beach.
- Psychological well-being was higher post-intervention.
- Those who recently visited the beach reported higher life satisfaction in particular.
- Greater satisfaction with personal safety and community belonging were key mediators.

ARTICLE INFO

Keywords:
Blue space
Blue Health
Urban beach
Intervention
Urban acupuncture

ABSTRACT

Observational studies have suggested that people with better access to attractive, safe, and inclusive blue spaces enjoy higher psychological well-being, with particular benefits for those living in deprived urban areas. However, intervention studies are scarce. To help bridge this gap we conducted a repeat cross-sectional study exploring local resident and visitor well-being before and after a small-scale intervention aimed at improving the quality of an urban beach area in a deprived neighbourhood in Plymouth, United Kingdom. Physical alterations were co-created with local stakeholders and residents, and accompanied by a series of on-site community events. Key outcomes were self-reported psychological well-being, satisfaction with personal safety and community belonging, and perceptions of site quality. Adjusted linear models showed that positive well-being (B = 7.42; 95% CI = 4.18–10.67) and life satisfaction (B = 0.40; 95% CI = 0.11–0.70) were both higher after the intervention compared to before, with associations for life satisfaction stronger among those who visited the site in the last four weeks. Associations with positive well-being were partially mediated by greater satisfaction with community belonging; and associations with life satisfaction were partially and independently mediated by greater satisfaction with personal safety and community belonging. Although caution needs to be taken due to the repeat cross-sectional design and the sampling of site visitors as well as local residents, the findings support the idea that environmental improvements to urban blue spaces can foster better psychological well-being, and underline the importance of community involvement in the process.

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https://doi.org/10.1016/j.landurbplan.2021.104232
Received 4 December 2020; Received in revised form 8 July 2021; Accepted 18 August 2021
Available online 25 August 2021

1. Introduction

Increasing urbanisation poses various risks to physical and psychological health leading to growing interest in the design of urban areas for improved public health and well-being (Grant et al., 2017; Sallis et al., 2016). A wealth of observational studies have suggested that living in greener urban areas is associated with better health and well-being outcomes, even after controlling for a range of potential socio-demographic confounds (Gascon et al., 2016; Twohig-Bennett & Jones, 2018; van den Berg et al., 2015; van den Bosch & Sang, 2017). However, several questions remain.

First, the vast majority of work focuses on green spaces (e.g. playing fields, woodlands etc.). However, there is growing evidence that blue spaces – i.e. outdoor environments that prominently feature water such as rivers, lakes, and beaches (Grellier et al., 2017) – may be beneficial for psychological well-being in particular (Gascon, Zijlema, Vert, White, & Nieuwenhuijsen, 2017). For example, living near blue spaces has been associated with greater self-reported mental health (Garrett, Clitherow, White, Wheeler, & Fleming, 2019a), less anxiety, mood disorders, and distress (de Vries et al., 2016; Nutsford, Pearson, Kingham, & Reitsma, 2016), and lower depression scores (Dempsey, Devine, Gillespie, Lyons, & Nolan, 2018). Moreover, visiting blue spaces has been positively associated with positive well-being (White et al., 2021) and happiness (De Vries, Nieuwenhuizen, Farjon, Van Hinsberg, & Dirkx, 2021; MacKerron & Mourato, 2013).

Second, most of our insights are derived from observational work focusing on neighbourhood exposure in general through, for instance, the quantity of 'greenness' surrounding the home (Labib, Lindley, & Huck, 2020). It remains unclear how important the quality of these places is for health-related outcomes (van den Berg et al., 2015). Factors such as perceived safety, the presence of facilities, management practices, biodiversity, and community involvement, are all likely to be associated with quality appraisals, as well as a range of well-being outcomes (e.g. Garrett et al., 2019b; Pitt, 2019; Rugel, Carpiano, Henderson, & Brauer, 2019; van den Berg et al., 2019). Nevertheless, more work is needed to unpack the associations between blue spaces and psychological well-being, especially with respect to environmental qualities in and around them, given that many large cities and urban areas are deliberately sited on large rivers, lakes and coastlines (White, Elliott, Gascon, Roberts, & Fleming, 2020).

Third, despite that there is a growing interest in the quality of green and blue spaces, there still remain relatively few intervention studies that examine if physical changes to these spaces aids to human health and well-being, and those that have been executed have shown mixed results (e.g. Branas et al., 2011; South, Hohl, Kondo, MacDonald, & Branas, 2018; Vert et al., 2019; Ward Thompson et al., 2019). Intervention research can build on and extend insights from observational research. Selective migration patterns, for example, mean that people with better health and well-being may move to areas with better access to higher quality green and blue spaces, in part because they can afford to do so (Wheeler et al., 2015), and thus residual cofounding may occur despite researchers' best efforts to reduce it in correlational studies (McCormack & Shiell, 2011). Furthermore, there is evidence that when interventions to improve local green and blue spaces are undertaken, 'gentrification' can occur, where due to the increased attractiveness of the location, wealthier, healthier populations move into the area (Triguero-Mas et al., 2021; Wolch, Byrne, & Newell, 2014). What is needed, are more studies that examine interventions that take place where the resident population is relatively stable, for instance in areas where social housing predominates, and inward migration from wealthier residents is limited.

In an attempt to partly explore these three issues, the present study examined the psychological well-being of cross-sections of local residents and visitors to an urban beach area, located in a relatively deprived district of Plymouth, United Kingdom (UK) with high levels of social housing, before and after an environmental intervention.

1.1. Potential benefits of blue spaces in deprived areas

Residents of socio-economically deprived neighbourhoods tend to have poorer mental health and well-being than those in more affluent neighbourhoods (Kim, 2008). Additionally, low socio-economic status has been associated with mental health disorders and lower life satisfaction (Barger, Donoho, & Wayment, 2009; Freeman et al., 2016; Lorant et al., 2018). Landscape interventions to increase access to high quality natural environments may help to mitigate these inequalities because evidence suggests that the benefits of nature in the living environment on well-being are most pronounced in socio-economically deprived areas (e.g. Brown et al., 2018; Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006; Mitchell & Popham, 2008; Mitchell, Richardson, Shortt, & Pearce, 2015).

Concerning blue space in particular, the odds of good self-reported general health have been shown to be less disparate across deprivation quintiles for those living closest to the coast in England (Wheeler, White, Stahl-Timmins, & Depledge, 2012). Similarly, evidence suggests those living closest to the coast in England experience better mental health, and that the association is strongest among households with the lowest income (Garrett et al., 2019a). In addition, positive associations between blue space availability and both general health and mental health have been shown to be stronger among those with the lowest levels of educational attainment (i.e. a proxy of socio-economic status) (de Vries et al., 2016).

Among people with a lower socio-economic status, the use of natural environments is generally lower (Boyd, White, Bell, & Burt, 2018). However, leisure visits may play a role in the psychological health benefits of such environments (Van den Berg et al., 2016). Cross-sectional studies have suggested that leisure visits to blue spaces may be important for short-term psychological well-being (White, Pahl, Ashbullby, Herbert, & Depledge, 2013), and that greater visit frequency is associated with better psychological well-being among older adults in Hong Kong (Garrett et al., 2019b). Furthermore, visits to coastal blue spaces appear to be more equitable across socio-economic groups, than visits to, for example, woodland environments (Elliott et al., 2018). This underlines the need for interventions, which aim to increase the use of and access to blue spaces in deprived areas.

1.2. Potential mechanisms

Considering landscape interventions that have been done (e.g. Hunter et al., 2019), we expect that blue space interventions may foster well-being benefits through at least three mechanisms. First, improvements to environmental quality may facilitate greater health benefits. Previous research has suggested that better quality residential greenspace (broadly defined) is associated with better general and mental health (Feng & Astell-Burt, 2018; van Dillen, de Vries, Groenewegen, & Spreeuwenberg, 2012). These environmental qualities may come in the form of improved access (Lee & Maheswaran, 2011; Roe, Aspinall, & Ward Thompson, 2016) and facilities (Kaczynski, Potwarka, & Saelens, 2008; McCormack, Rock, Toohey, & Hignell, 2010; Peschardt & Stigsdotter, 2013). With respect to blue spaces, Garrett et al. (2019b) showed that the presence of wildlife and good facilities were factors associated with more blue space visits among older adults. Additionally, intervention research showed that improvements to the accessibility of a riverbank in a deprived urban area of Barcelona, Spain, led to a 25% increase in recreational use, although the subsequent impacts on health or well-being were not quantified (Vert et al., 2019).

Second, blue space renovations may contribute to greater perceptions of safety. Perceptions and indicators of the safety of one's neighbourhood and nearby green space have been shown to be prominent determinants of physical health and mental health. For example, feelings of less neighbourhood safety have been associated with higher prevalence of depression (Generaal et al., 2019). Green spaces that are perceived to be safe or have fewer indicators of incivilities have been

associated with improved physical activity (Akpinar, 2016; Hamilton, Kaczynski, Fair, & Lévesque, 2017; Weimann et al., 2017); and residential green space with fewer indicators of incivilities (e.g. more litter and graffiti) has been associated with higher self-reported health and lower rates of depression (Brindley, Cameron, Ersoy, Jorgensen, & Maheswaran, 2019; Mears, Brindley, Jorgensen, & Maheswaran, 2020). Qualitative investigations of blue spaces suggest that perceptions of safety – or increased risk – strongly influences their use (Pitt, 2019). However, quantitative investigations of blue spaces did not find meaningful associations between perceptions of safety and their use (Vert et al., 2019) or visit frequency (Garrett et al., 2019b), but in the latter study, perceptions of safety was associated with feelings of well-being during the visit.

Third, community belonging may play a role because previous research has suggested that sense of community and social cohesion (extent of connectedness with neighbours) mediate the association between green space and improved mental health outcomes (Rugel et al., 2019; van den Berg et al., 2019). The importance of community involvement in woodland interventions in deprived urban communities has been demonstrated recently (Ward Thompson et al., 2019), and is supported by the conclusions of a systematic review of environmental interventions (Hunter et al., 2019). In addition, community co-creation of environmental interventions has been shown to be an important contributor to positive health outcomes in public health programmes (Richardson, Goss, Pratt, Sharman, & Tighe, 2012).

1.3. Present study

The BlueHealth project (Grellier et al., 2017) aimed to examine the conditions and mechanisms through which blue space may support human health and well-being. One aspect of the project involved conducting small-scale landscape interventions, or so called 'urban blue acupuncture' interventions in several sites around Europe. Underpinning the idea of 'urban blue acupuncture' is that modest landscape changes targeted to the local situation and co-created with local community involvement may have large impacts on the health and well-being of the local community (Bell et al., 2020). The present study describes findings from one such 'urban blue acupuncture' intervention concerning a neglected urban beach park named Teats Hill, situated in one of the most deprived areas of Plymouth, UK, which was co-created with the local community and stakeholders. The main objective of this present study was to examine associations between the 'urban blue acupuncture' intervention and the psychological well-being of local residents and visitors to the site, and the reasons underlying any positive associations. We tested three hypotheses:

1) Local residents and visitors would report more positive emotional states within the last two weeks (positive well-being) and higher satisfaction with life in general (life satisfaction) after (compared to before) the 'urban blue acupuncture' intervention at Teats Hill;
2) The positive associations between the intervention and these two outcomes would be especially prominent in those who visited Teats Hill more often in the last four weeks;
3) The associations between the intervention and positive well-being and life satisfaction would be mediated by perceived site quality, satisfaction with personal safety, and satisfaction with feeling part of the community (community belonging).

2. Method

The study design and materials were approved by the University of Exeter's College of Medicine and Health Research Ethics Committee (Ref: Nov16/B/112). Alongside the work reported here, evaluation was supplemented with behavioural observations, interviews, and environmental audits (Bell et al., 2020). These evaluations were outside the scope of the present study, and will be reported elsewhere.

2.1. 'Urban blue acupuncture' intervention

Teats Hill is a coastal area with a small beach, green space, playground, and other amenities (e.g. ball court, picnic benches, and public slipway for transporting boats in and out of the water). The main access points are located directly next to a social housing estate, and the two sides of the site are adjacent to a marina (not directly accessible through the site) and a large public aquarium. Prior to the renovations, many aspects of the site had fallen into disrepair. For example, the slipway was severely damaged and was blocked by large boulders to prevent access, the access road had become an unofficial car park, and there was considerable overgrown vegetation and litter accumulation on the shore. The 'urban blue acupuncture' intervention at Teats Hill was partly subsidised by the BlueHealth project, and formed part of the UK's Big Lottery funded Active Neighbourhoods Project, which facilitated improvements, health programmes, and community-related activities in five areas of Plymouth, and built on similar greenspace projects previously undertaken locally (Richardson et al., 2012).

In coordination with landscape architects (SB and HSM), a suite of potential improvements were proposed and plans for community events, public consultations, and legacy were made. A steering group of stakeholders from the city council, housing association (who owned the nearby social housing), Devon Wildlife Trust, Marine Biological Association, National Marine Aquarium, local schools and charitable organisations, local universities and research institutions, conservation groups, and local councillors oversaw the improvement process. The physical plans were laid out at a number of public consultations that took place at the site itself throughout 2017, and were carefully refined with local community input through this process. By including this co-creation process, we tried to ensure that the re-design of the site met the needs and wishes of local residents (Bell et al., 2020).

The regeneration was carried out in winter 2017/2018 (Figs. 1 and 2). It included: the construction of a small open-air theatre with seating facing outward towards the water; preventing parking on the slipway; extensive landscaping; partial renovation of the slipway; and playground improvements. Playground improvements included the introduction of new nautically themed play equipment and pictorial representations of the sailing of the Mayflower to the United States in 1620, which took place in Plymouth directly opposite the site. Information boards were installed to enhance knowledge about the biodiversity, environmental quality of the site, and history of the area. Please see Bell et al. (2020) and for more details about the intervention.

2.2. Data collection and sample.

This study employed a repeat cross-sectional pre-post design. Pre-intervention data were collected between June and September 2017. Post-intervention data were collected between June and August 2018. This period was chosen to reduce potential seasonal response biases in recreational visits (Elliott et al., 2018), and to reduce potential novelty effects. That is, the post-intervention data collection was approximately four months after the completion and 'opening' of the renovated site, which means that local residents and visitors were already likely to be acquainted with the renovations, and that our findings represent associations with the renovations as opposed to associations with the co-creation process. Data were collected by means of structured face-to-face interviews (surveys), conducted by a professional market research company. The interviews were guided by scripted instructions and show-cards displaying the location and photos of the site.

The primary recruitment method, the 'doorstep method', involved systematic sampling of households in the seven Output Areas (small census geographies constructed from clusters of adjacent unit postcodes) that were closest to the Teats Hill site (Fig. 3). Specifically, alternating addresses in these seven Output Areas were targeted in the first wave of data collection (i.e. pre-intervention) with the remaining addresses targeted in the second wave (i.e. post-intervention). The aim of this

Fig. 1. Photos of Teats Hill before and after the 'urban blue acupuncture' intervention (photos taken by SB).

approach was to reduce bias from, for example, sampling blocks of housing with different characteristics in the first and second waves that could unduly confound the results. Interviewers attempted up to three door knocks at each residence on different days of the week and different times of day. Of the 549 addresses selected pre-intervention, interviewers managed to speak to individuals in 200 households. Of these 200, 139 consented to the interview (69.5%) and 61 declined (30.5%). Post-intervention, of 545 selected addresses, interviewers managed to speak to 255 residents, of which 160 consented (62.7%) to be interviewed and 95 declined (37.3%).

Due to the number of residents that the interviewers were unable to reach via the doorstep method, a second strategy for data collection was adopted in order to increase statistical power: the 'neighbourhood method'. Interviewers directly approached people outside in the local neighbourhood including on the path that ran along the north edge of the site linking our target population to the barbican part of the city (via a bridge or water taxi) and the aquarium. In inclement weather, some people were interviewed in the forecourt area of the aquarium due to a large overhanging roof, although any visitors from outside of the city were quickly screened and not included in the study. A further 345 participants were recruited via this method: 173 pre-intervention and 172 post-intervention. Participant postcodes were recorded to establish approximate home proximity to the site. This data found that 18% of interviewees recruited through the neighbourhood method lived in our seven targeted Output Areas. Since a single postcode spans several houses, we were unable to tell whether a resident recruited through the doorstep method also took part through the neighbourhood method due to this mix of recruitment strategies. We recognise that introducing a second recruitment strategy adds inevitable variance, so we performed sensitivity analyses to explore the influence of this second strategy.

In total, 653 structured interviews were conducted. Twelve participants interviewed at the site were from outside of the greater Plymouth region and were excluded so that the final sample only consisted of local residents more broadly. One participant had numerous missing responses – and no response on the outcome and mediating variables – so data from this participant were removed. This left a final sample of 640 participants: 309 pre-intervention (doorstep method = 141; neighbourhood method = 168) and 331 post-intervention (doorstep method 166; neighbourhood method = 165).

2.3. Measures

2.3.1. Psychological well-being

Two measures of psychological well-being were included: positive well-being and life satisfaction. *Positive well-being* was measured using the World Health Organization's five-item Well-being Index (WHO-5). The WHO-5 is a widely used measure of recent psychological well-being, and has previously shown excellent validity in intervention studies (Topp, Østergaard, Søndergaard, & Bech, 2015). Previous use of the scale has demonstrated that socio-economic inequalities in current well-being are lower among people with good access to green space (Mitchell et al., 2015), and that weekly visits to blue space are associated with greater odds of high well-being in older adults (Garrett et al., 2019b). The WHO-5 was included in this study to assess if the environmental improvements may be associated with recent emotional states. More specifically, items assess the extent to which respondents have felt five positive emotional states (e.g. "I have felt calm and relaxed" and "I have felt active and vigorous") in the past two weeks. These five items were scored on a six-point scale ranging from 0 ("not at all") to 5 ("all of the time"). Scores are summed and multiplied by 4 to give a score out of 100 with higher scores representing better well-being. The measure had good reliability in the present study (Cronbach $\alpha = 0.84$).

Life satisfaction was measured using a one-item question which reflects how participants evaluate their life as a whole as developed by the Organisation for Economic Cooperation and Development (OECD, 2013) using wording from the European Social Survey (ESS, 2018). Life satisfaction has been commonly used as a measure of evaluative well-being (Anderson, Mikulic, Vermeylen, Lyly-Yrjanainen, & Zigante, 2009; ESS, 2018; Inglehart, Puranen, Pettersson, Nicolas, & Esmer, 2015). Previous studies have shown that higher life satisfaction has been associated with window nature views (Chang et al., 2020), residential coastal proximity (Ambrey & Fleming, 2014), and more frequent nature visits (White et al., 2019), amongst other exposures. Life satisfaction was included in this present study to assess if the environmental improvements were associated with longer-term, more global well-being. Participants were asked "*All things considered, how satisfied are you with your life as a whole nowadays*?" This item was scored on a scale ranging from zero ("not at all satisfied") to ten ("completely satisfied").

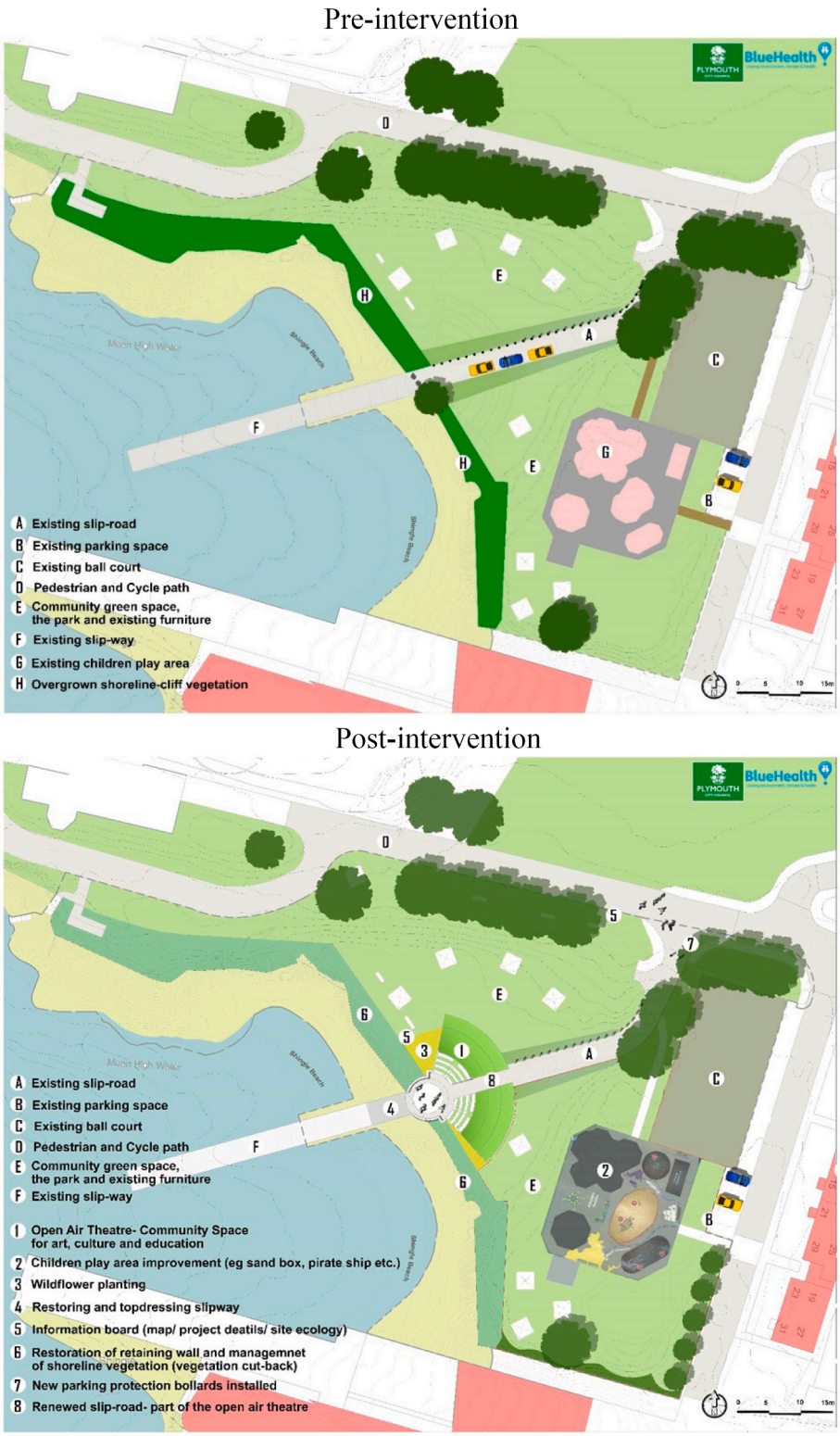

Fig. 2. Overview of Teats Hill before and after the 'urban blue acupuncture' intervention.

2.3.2. *Visit frequency*

All interviewees, regardless of recruitment method (i.e. doorstep or neighbourhood), were asked how often they had visited Teats Hill in the last four weeks, with response options: "not at all in last four weeks", "once or twice in the last four weeks", "once a week", and "several times a week". To maintain sufficient statistical power, we created a binary variable for those who visited at least once and those who had not visit Teats Hill in the last four weeks. One person did not respond to this question and was therefore not included in corresponding stratified analyses. Our interview schedule was adapted for the neighbourhood recruitment method so that people interviewed who were intercepted adjacent to the site were told that reporting the frequency of visits in the last 4 weeks to Teats Hill did not include their visit at that present time.

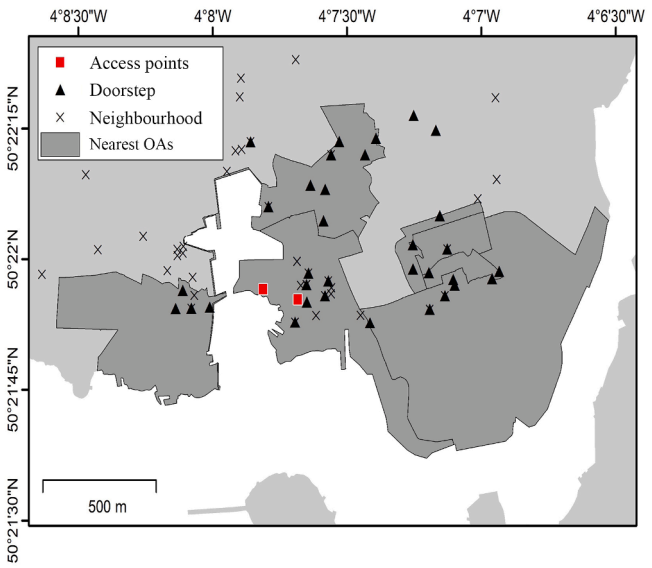

Fig. 3. The seven output areas (OAs) nearest the Teats Hill site, the two access points to Teats Hill, and postcodes of participants recruited through the doorstep method (Doorstep) and the neighbourhood method (Neighbourhood).

2.3.3. Mediating variables

Three possible mediating factors were identified: perceived site quality, as well more general satisfaction with personal safety and feeling part of the community (community belonging). *Perceived site quality* was measured using a one-item question derived from the PHENOTYPE survey (Nieuwenhuijsen et al., 2014). Participants were asked: "*Overall, how would you describe the quality of this location?*" This item was scored on a five-point scale ranging from one ("very bad") to five ("very good"). Satisfaction with *personal safety and community belonging* were both measured with one-item measures derived from the Personal Well-being Index (International Wellbeing Group, 2013). Participants were first told that the following questions were about their well-being in general and then asked "*How satisfied are you with how safe you feel?*" and "*How satisfied are you with feeling part of your community?*" Similar to the global life satisfaction scale, perceived personal safety and community belonging were measured on a scale ranging from zero ("not at all satisfied") to ten ("completely satisfied").

2.3.4. Confounders

Because of the study design, several demographic, socio-economic, and environmental factors were identified as possible confounding variables (e.g. Lee & Maheswaran, 2011; Modini et al., 2016; Schipperijn, Stigsdotter, Randrup, & Troelsen, 2010; White, Wheeler, Herbert, Alcock, & Depledge, 2014); and data on them were collected to include in analyses to reduce potential alternative explanations for the results. Demographic and socio-economic controls (in many cases reduced to binary categories given the sample size) included gender (male; female), age (18–34 years; 35–64 years; 65 years and older), self-perceived ethnic minority group membership in the UK (no; yes), being in a long-term relationship (no; yes), children in household (none; one or more), work status (in paid work; not), household income (prefer not to answer; less than £14,548; and more than £14,548), garden access (no access to private garden or outdoor space; access to private garden or outdoor space), dog ownership (no; yes), physical activity (<5 days/week; >5 days/week), and perceived general health (poor; good). See Supplementary Table 1 for the original scales and construction of the variables.

Environmental variables that were identified as possible confounders included recruitment method (doorstep; neighbourhood), and residential proximity to Teats Hill (Wheeler et al., 2012). Residential proximity was calculated as the straight-line distance from the mid-point of the street of residence to the nearest entrance point to Teats Hill (two entrance points existed) using ArcGIS (version 10.5.1; ESRI Inc.). Three categories were constructed from these distances: Within 500 m, 500–750 m, and 750 m or further. Within the first 500 m inland of the site, there were no other publicly accessible natural environments, thus indirectly this also controlled for accessibility to other green spaces.

2.4. Statistical analyses

A series of chi-squared tests and t-tests were performed to analyse pre-post intervention differences in sample characteristics and mediation variables. Pre-post intervention differences in positive well-being and life satisfaction were analysed using linear regression analyses. All assumptions for linear regression were considered and satisfied. Associations are presented as unstandardized regression coefficients (B) with their 95% Confidence Interval (CI). Model fit was estimated with R^2. Analyses were performed in IBM SPSS Statistics 26.

First, we explored direct associations between the intervention and positive well-being and life satisfaction. Model 1 presents crude associations; Model 2 presents associations adjusted for demographic and socio-economic controls; and Model 3 presents associations adjusted for demographic, socio-economic, and environmental controls. Due to missing individual-level and site-related data, sample sizes differed between Models 1, 2, and 3. The main text of this present study presents associations based on list-wise exclusion of respondents with missing data to maintain as much power in each analysis as possible. Supplementary Table 2 presents associations in which respondents with any missing data were excluded from further analysis.

Second, to explore the role of recent visits and thus exposure to the site, we stratified our analyses on whether the person had vs. had not visited Teats Hill in the last 4 weeks. Furthermore, given the potential importance of recruitment method on our results, a sensitivity analysis was also conducted which stratified the models by recruitment method (doorstep vs. neighbourhood method). The results of these stratified analyses are presented in Supplementary Table 3.

Third, we explored if the associations between intervention and positive well-being and life satisfaction were mediated by perceived site quality, satisfaction with personal safety, and satisfaction with community belonging. For these outcomes, simple mediation analyses were performed using the Process Macro v3.2, Model 4 with bootstrapping (5000 samples) (Hayes, 2018). The mediation analyses were also adjusted for demographic, socio-economic, and environmental controls.

3. Results

The total study sample ($N = 640$) comprised 348 females (54.4%), mean age was 46.70 (SD = 18.81, range 18–92). The majority did not report belonging to a minority ethnic group (91.1%), and lived within 750 m from Teats Hill (51.1%). Post-intervention, there were more participants who reported being in a long-term relationship, did not state their household income, had access to a private garden or outdoor space; and fewer participants who had children, owned a dog, and were physically active five days per week or more compared to pre-intervention (Table 1).

Pre-intervention, 44% ($n = 136$) had visited Teats Hill at least once and 56% ($n = 173$) had not visited Teats Hill in the previous four weeks. Post-intervention, 38.7% ($n = 128$) had visited, and 61% ($n = 202$) had not. Among those who had not visited Teats Hill, there were more participants who had access to a private garden or outdoor space and did not state their household income; and fewer participants who reported belonging to an ethnic minority group, had children, and owned a dog at post-test than pre-intervention. Among those who visited Teats Hill at least once, there were more participants who were female, considered themselves being in a long-term relationship, had children, did not state their household income; and fewer participants who owned a dog and who lived within 500 m of Teats Hill post-intervention than pre-

Table 1
Characteristics of total Teats Hill study sample (N = 640), and stratified by those who visited Teats Hill at least once (n = 264) and those who had not visit Teats Hill in the previous four weeks (n = 375).

		Total sample				At least one visit				No visits			
		Pre-intervention (n = 309)		Post-intervention (n = 331)		Pre-intervention (n = 136)		Post-intervention (n = 128)		Pre-intervention (n = 173)		Post-intervention (n = 202)	
		%	(n)	%	(n)	%	(n)	%	(n)	%	(n)	%	(n)
Demographic and socio-economic variables													
Gender	Male	48.2	(149)	43.2	(143)	54.4	(74)	38.3	(49)**	43.4	(75)	46.5	(94)
	Female	51.8	(160)	56.8	(188)	45.6	(62)	61.7	(79)	56.6	(98)	53.5	(108)
Age	18–34 years	36.2	(112)	33.8	(112)	33.8	(46)	28.9	(37)	38.2	(66)	37.1	(75)
	35–64 years	39.2	(121)	44.1	(146)	39.7	(54)	47.7	(61)	38.7	(67)	41.6	(84)
	65–92 years	23.3	(72)	21.8	(72)	25.7	(35)	23.4	(30)	21.4	(370)	20.8	(42)
	Missing	*1.3*	(4)	*0.3*	*(1)*	*0.7*	*(1)*			*1.7*	*(3)*	*0.5*	*(1)*
Minority ethnic group	No	89.3	(276)	92.7	(307)	89.7	(122)	89.8	(115)	89.0	(154)	94.6	(191)*
	Other	10.7	(33)	7.3	(24)	10.3	(14)	10.2	(13)	11.0	(19)	5.4	(11)
Long-term relationship	No	69.3	(214)	50.2	(166)***	74.3	(101)	46.9	(60)***	65.3	(113)	52.0	(105)**
	Yes	30.7	(95)	49.8	(165)	25.7	(35)	53.1	(68)	34.7	(60)	48.0	(97)
Children	0	47.6	(147)	73.1	(242)***	46.3	(63)	70.3	(90)***	48.6	(84)	74.8	(151)***
	≥1	51.8	(160)	26.6	(88)	53.7	(73)	28.9	(37)	50.3	(87)	25.2	(51)
	Missing	*0.6*	(2)	*0.3*	*(1)*			*0.8*	*(1)*	*1.2*	*(2)*		
In paid work	No	52.1	(161)	49.8	(165)	58.1	(79)	48.4	(62)	47.4	(82)	51.0	(103)
	Yes	47.9	(148)	50.2	(166)	41.9	(57)	51.6	(66)	52.6	(91)	49.0	(99)
Household income	No answer	46.3	(148)	61.0	(202)**	42.6	(58)	55.5	(71)*	49.1	(85)	64.4	(130)**
	<£14,548	22.3	(69)	15.4	(51)	27.9	(38)	16.4	(21)	17.9	(31)	14.9	(30)
	≥£14,548	31.4	(97)	23.6	(78)	29.4	(40)	28.1	(36)	32.9	(57)	20.8	(42)
Garden/outdoor space	No	41.4	(128)	31.1	(103)**	40.4	(55)	33.6	(43)	42.2	(73)	29.7	(60)*
	Yes	58.3	(108)	68.6	(227)	58.8	(80)	65.6	(84)	57.8	(100)	70.3	(142)
	Missing	*0.3*	*(1)*	*0.3*	*(1)*	*0.7*	*(1)*	*0.8*	*(1)*				
Dog owner	No	53.1	(164)	79.8	(264)***	46.3	(63)	76.6	(98)***	58.4	(1 0 1)	81.7	(1 6 5)***
	Yes	46.3	(143)	19.9	(66)	52.9	(72)	23.4	(30)	41.0	(71)	17.8	(36)
	Missing	*0.6*	*(2)*	*0.3*	*(1)*	*0.7*	*(1)*			*0.6*	*(1)*	*0.5*	*(1)*
Physical activity	<5days/week	54.0	(167)	63.4	(210)*	44.1	(60)	51.6	(66)	61.8	(107)	70.8	(143)
	≥5days/week	42.7	(132)	35.6	(118)	54.4	(74)	46.1	(59)	33.5	(58)	29.2	(59)
	Missing	*3.2*	*(10)*	*0.9*	*(3)*	*1.5*	*(2)*	*2.3*	*(3)*	*4.6*	*(8)*		
General health	Low	25.2	(78)	29.6	(98)	19.1	(26)	23.3	(30)	30.1	(52)	33.7	(68)
	High	71.5	(221)	68.9	(228)	77.2	(105)	74.2	(95)	67.1	(116)	65.3	(132)
	Missing	*3.2*	*(10)*	*1.5*	(5)	*3.7*	*(5)*	*2.3*	*(3)*	*2.9*	*(5)*	*1.0*	*(2)*
Environmental variables													
Recruitment method	Doorstep	45.6	(141)	50.2	(166)	35.3	(48)	43.8	(56)	53.8	(93)	54.5	(110)
	Neighbourhood	54.4	(168)	49.8	(165)	64.7	(88)	56.3	(72)	46.2	(80)	45.5	(92)
Residential proximity	<500 m	28.2	(87)	21.5	(71)	42.6	(58)	26.6	(34)*	16.8	(29)	18.3	(37)
	500–750 m	24.9	(77)	27.8	(92)	13.2	(18)	21.1	(27)	34.1	(59)	32.2	(65)
	≥750 m	43.7	(135)	36.3	(120)	40.4	(55)	36.7	(47)	46.2	(80)	35.6	(72)
	Missing	*3.2*	*(10)*	*14.5*	*(48)*	*3.7*	*(5)*	*15.6*	*(20)*	*2.9*	*(5)*	*13.9*	*(28)*

* Difference between pre-test and post-test $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 2
Means (M) with standard deviations (SD) of key outcomes and potential mediators in the total Teats Hill study sample, and stratified by those who visited Teats Hill at least once (n = 264) and those who had not visit Teats Hill in the previous four weeks (n = 375).

	Total sample				At least one visit				No visits			
	Pre-intervention (n = 309)		Post-intervention (n = 331)		Pre-intervention (n = 136)		Post-intervention (n = 128)		Pre- intervention (n = 173)		Post-intervention (n = 202)	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Outcome variables												
Positive well-being	66.76	(20.58)	72.55	(19.02)***	71.40	(18.90)	76.42	(16.28)*	63.19	(21.17)	69.97	(20.19)**
Missing (n)		*(19)*		*(11)*		*(9)*		*(4)*		*(10)*		*(7)*
Life satisfaction	7.92	(1.93)	8.13	(1.60)	8.08	(1.99)	8.37	(1.20)	7.80	(1.88)	7.96	(1.79)
Missing (n)		*(9)*		*(5)*		*(4)*		*(2)*		*(5)*		*(3)*
Mediating variables												
Perceived site quality	2.97	(1.00)	3.60	(0.89)***	2.90	(1.10)	3.98	(0.91)***	3.02	(0.92)	3.36	(0.80)***
Missing (n)				*(5)*								*(5)*
Personal safety	8.18	(1.77)	8.44	(1.38)*	8.23	(1.85)	8.45	(1.34)	8.14	(1.71)	8.42	(1.42)
Missing (n)		*(5)*		*(5)*		*(1)*		*(2)*		*(4)*		*(3)*
Community belonging	6.72	(2.52)	7.26	(2.17)**	7.01	(2.51)	7.51	(1.92)	6.50	(2.51)	7.08	(2.30)*
Missing (n)		*(11)*		*(3)*		*(4)*		*(1)*		*(7)*		*(2)*

* Difference between pre-test and post-test $p < 0.05$, ** $p < 0.01$, *** $p < 0.00$.

intervention.

With respect to the potential mediators, perceived site quality, and satisfaction with personal safety and community belonging were all rated higher post-intervention than pre-intervention (Table 2). Among those who visited the site, only perceived site quality was rated higher post-intervention than pre-intervention. Among those who did not visited the site, both perceived site quality and satisfaction with community belonging were rated higher post-intervention than pre-intervention.

3.1. Associations with positive well-being

Mean positive well-being was 66.78 (SD = 20.58, range 4–100) pre-intervention, and 72.55 (SD = 19.02, range 12–100) post-intervention. The pre-post difference was 5.76 points (95% CI = 2.62–8.91; $p < 0.001$; Table 3). Supporting Hypothesis 1, adjusted linear regression analyses showed that positive well-being remained higher post-intervention than pre-intervention after adjustments for demographic and socio-economic controls (B = 7.15; 95% CI = 3.98–10.32), and environmental controls (B = 7.42; 95% CI = 4.18–10.67).

Stratified by visit frequency, and refuting Hypothesis 2, adjusted linear regression analysis showed that the association between the intervention (i.e. pre-post difference) and positive well-being was equally strong for people who had visited Teats Hill in the previous 4 weeks (B = 6.19, 95% CI = 1.25–11.13; $p < 0.05$) and those who had not (B = 7.58, 95% CI = 3.07–12.09; $p < 0.01$). Furthermore, stratified by recruitment method, adjusted linear regression analyses showed that post-intervention positive well-being was higher than pre-intervention for both people who were recruited with the doorstep method (B = 9.92, 95% CI = 5.48–14.36, $p < 0.001$), and (not statistically significant) among those who were recruited with the neighbourhood method (B = 3.38, 95% CI = −2.26–9.92, $p = 0.22$, Supplementary Table 3).

In partial support of Hypothesis 3, adjusted mediation analyses – in the total Teats Hill sample – showed that satisfaction with community belonging (indirect effect = 0.57; 95% CI = 0.03–1.30) partially mediated the association between the intervention (i.e. pre-post difference) and positive well-being. Neither perceived site quality nor satisfaction with personal safety showed evidence of mediation (Fig. 4). Differences in satisfaction with community belonging explained 7% of the total effect on positive well-being.

3.2. Associations with life satisfaction

Mean life satisfaction was 7.92 (SD = 1.93, range 1–10) pre-intervention, and 8.13 (SD = 1.60, range 0–10) post-intervention. The pre-post difference was 0.21 points (95% CI = −0.07–0.48; $p = 0.15$). Adjustments for potential confounders strengthened this association. Supporting Hypothesis 1, post-intervention life satisfaction was higher than pre-intervention after adjustments for demographic and socio-economic controls (B = 0.35; 95% CI = 0.07–0.63; $p < 0.05$), and environmental controls (B = 0.40; 95% CI = 0.11–0.70; $p < 0.01$).

Stratified by visit frequency and supporting Hypothesis 2, adjusted linear regression analyses showed that post-intervention life satisfaction was 0.54 points (95% CI = 0.08–1.01; $p < 0.05$) higher than pre-intervention among people who had visited Teats Hill in the previous four weeks. Among people who had not visited, this association was weaker (and not statistically significant). Furthermore, stratified by recruitment method, adjusted linear regression analyses showed that post-intervention life satisfaction was (not statistically significant) higher than pre-intervention for both people who were recruited with the doorstep method (B = 0.24, 95% CI = −0.18 to 0.66, $p = 0.27$) and those who were recruited with the neighbourhood method (B = 0.43, 95% CI = −0.10 to 0.96, $p = 0.11$, Supplementary Table 3).

In partial support of Hypothesis 3, adjusted mediation analyses – in the total Teats Hill sample – showed that satisfaction with community belonging (indirect effect = 0.06; 95% CI = 0.01–0.14) again partly mediated the association between the intervention (i.e. pre-post difference) and life satisfaction. This time, satisfaction with personal safety (indirect effect = 0.09; 95% CI = 0.04–0.19) also partly mediated the association between the intervention and life satisfaction; while perceived site quality did not show evidence of mediation (Fig. 5). Satisfaction with personal safety explained 22.6%, and community belonging explained 16.4%, of the total effect of the intervention on life satisfaction.

4. Discussion

To complement the existing, predominantly observational research examining the effects of blue spaces on human well-being, this study examined if a 'urban blue acupuncture' intervention at an urban coastal site was associated with improvements in local resident and visitor psychological well-being. Our first hypothesis, that psychological well-being would be higher after the intervention, was supported. Local residents and visitors of the Teats Hill site tended to report higher

Table 3
Results of linear regression analyses on the association between the 'urban blue acupuncture' intervention and psychological well-being in the total Teats Hill study sample, and stratified by those who visited Teats Hill at least once and those who had not visit Teats Hill in the previous four weeks.

		Total sample			At least one visit			No visits		
		B	95% CI	n/R^2	B	95% CI	n/R^2	B	95% CI	n/R^2
Positive well-being										
Unadjusted model	Pre-intervention (ref)									
	Post-intervention	5.76	2.62–8.91***	610/0.02	5.02	0.63–9.41*	251/0.02	6.78	2.47–11.09**	358/0.03
Model 2	Pre-intervention (ref)									
	Post-intervention	7.15	3.89–10.32 ***	587/0.24	5.57	0.86–10.28*	224/0.20	7.89	3.58–12.20***	342/0.28
Model 3	Pre-intervention (ref)									
	Post-intervention	7.42	4.18–10.67***	542/0.28	6.19	1.25–11.13*	226/0.26	7.58	3.07–12.09**	315/0.29
Life satisfaction										
Unadjusted model	Pre-intervention (ref)									
	Post-intervention	0.21	−0.07–0.48	626/0.003	0.29	−0.12–0.69	258/0.01	0.17	−0.21–0.54	367/0.002
Model 2	Pre-intervention (ref)									
	Post-intervention	0.35	0.07–0.63*	604/0.23	0.47	0.05–0.90*	251/0.22	0.25	−0.12–0.63	352/0.28
Model 3	Pre-intervention (ref)									
	Post-intervention	0.40	0.11–0.70**	557/0.23	0.54	0.08–1.01*	231/0.24	0.32	−0.07–0.71	325/0.28

B = unstandardized regression coefficient, CI = Confidence Interval, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, Model 2 is adjusted for demographic and socio-economic controls (i.e. gender, age, ethnicity, long-term relationship status, children, work status, household income, accessibility garden or outdoor space, dog ownership, and general health), Model 3 is adjusted for demographic and socio-economic and environmental controls (i.e. recruitment method and residential proximity).

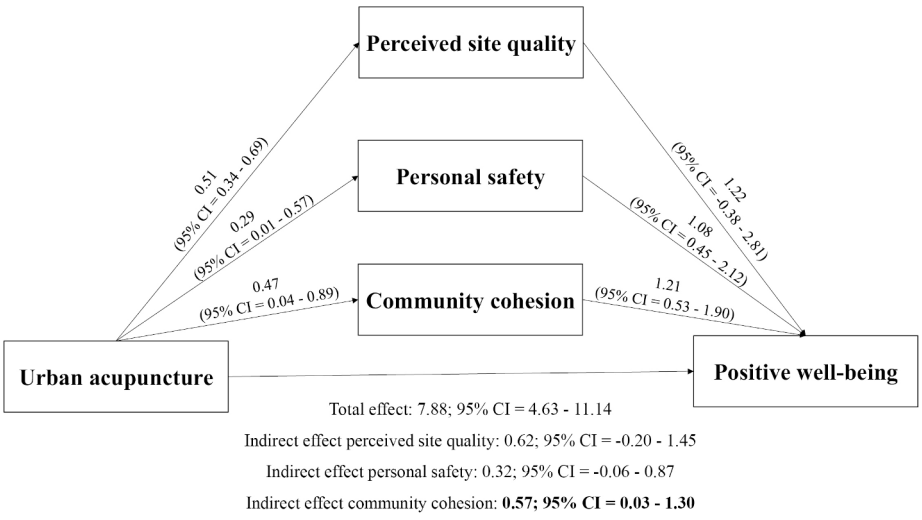

Fig. 4. Mediation model with perceived site quality, satisfaction with personal safety, and **satisfaction with community belonging** as potential mediators in the association between the 'urban blue acupuncture' intervention and **positive well-being** in the total Teats Hill study sample, adjusted for demographic, socio-economic, and environmental controls (n = 533).

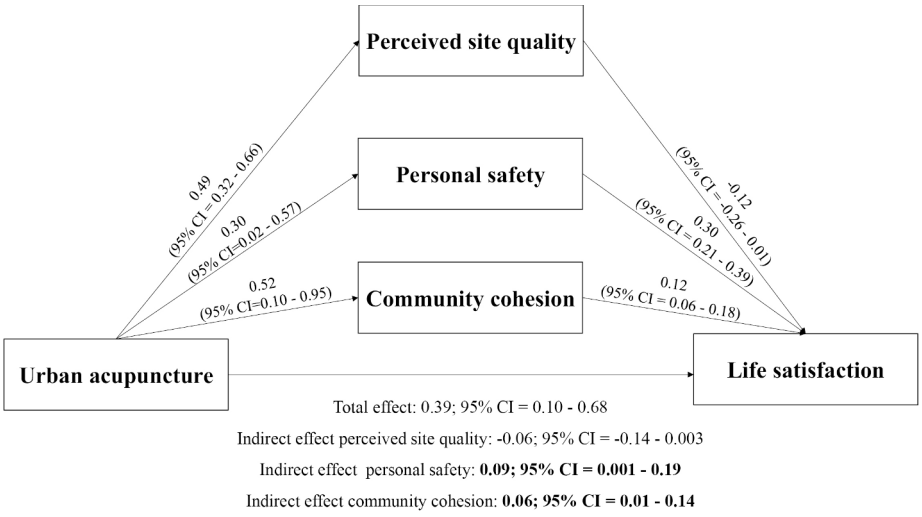

Fig. 5. Mediation model of perceived site quality, **perceived satisfaction with personal safety, and satisfaction with community belonging** as potential mediators in the association between the 'urban blue acupuncture' intervention and **life satisfaction** in the total Teats Hill study sample, adjusted for demographic, socio-economic, and environmental controls (n = 548).

positive well-being and life satisfaction after the intervention than before. These associations were robust to adjustments for potential confounders, and associations with and without respondents with any missing data were comparable (Supplementary Table 2). Our findings are especially pertinent in light of the socio-economic deprivation in the area where the intervention took place; and lend support to previous findings which suggest that access to blue space may be particularly important for people with lower socio-economic status (de Vries et al., 2016; Garrett et al., 2019a; Wheeler et al., 2012).

Our second hypothesis, that these associations would be especially prominent among those who visited the site more frequently, was partly supported. Given that previous research highlights the importance of recreational visits for aspects of short- and long-term psychological well-being (e.g. Garrett et al., 2019b; White et al., 2013; White, Pahl, Wheeler, Depledge, & Fleming, 2017), we expected associations to be stronger among people who had visited recently. Supporting this, the association between the intervention and life satisfaction – but not positive well-being – seemed to be stronger among those who visited Teats Hill at least once than those who had not visited in the previous four weeks. A crucial difference between our outcome variables was that positive well-being had a relatively short recall period (two weeks), whereas life satisfaction was a more global and stable assessment. It is plausible that assessments of recent positive well-being were more susceptible to other circumstances implicit in the timing of the survey, whereas the assessments of life satisfaction might be less changeable with temporary circumstances. For instance, it may be that general improvements to one's local area (even if not frequently experienced directly oneself) can still improve one's general sense of well-being, in part due to awareness that the local area is valued (Cattell, Dines, Gesler, & Curtis, 2008), but also due to spill-over effects from improved well-being of one's neighbours (Fowler & Christakis, 2008). Nevertheless, it must be noted that previous research is mixed on the associations between visiting natural environments and life satisfaction (Laffan, 2018; White et al., 2017).

Our third hypothesis - that the associations with positive well-being and life satisfaction would be mediated by perceived site quality, satisfaction with personal safety, and satisfaction with community belonging - was also partly supported. Community belonging mediated

the association between the intervention and both outcomes; satisfaction with safety mediated the association between the intervention and life satisfaction only; and perceived site quality did not show evidence of mediating these associations. These findings may suggest that community satisfaction and community involvement are important factors to consider in blue space interventions, which also have been suggested by others (Hunter et al., 2019). The physical alterations to the site were accompanied by a series of organised community events across the year, which not only constituted consultations on the site plans, but were also aimed at inviting families and friends to socialise. It is plausible that this series of events and the co-creative aspects of the design process are at least partly responsible for reported levels of satisfaction with community belonging that in turn led to more positive well-being and life satisfaction (Jennings & Bamkole, 2019; van den Berg et al., 2019). Although it clouds scientific assessment of the role of environmental interventions *per se*, we think this co-creation process is a price worth paying to ensure that the intervention is meaningful for the community.

Additionally, the mediation findings suggest that satisfaction with personal safety, a key determinant of more global life satisfaction, also played a role in the success of the intervention. One of the many aims of the regeneration was to increase perceptions of safety of the local area (Bell et al., 2020). Although we did not measure this directly, the results for satisfaction with personal safety – a more general assessment of one's perceived safety - seem to suggest that the intervention may have been at least partially successful in this regard. Previous studies have demonstrated that safety of natural environments is associated with use and health outcomes (Baum, Ziersch, Zhang, & Osborne, 2009; McCormack et al., 2010). More intervention research is needed to further explore the role of the safety of blue spaces specifically as a prerequisite for health and well-being outcomes.

4.1. Strengths and limitations

A major strength of this study is that it is, as far as we are aware, the first to investigate the effects of an 'urban acupuncture' project at a blue space in a deprived urban area on resident psychological well-being. It thus provides insights into potential benefits, and lays the groundwork for future research and evaluations of similar interventions. We included two measures of psychological well-being: more short-term positive well-being and more global life satisfaction. Despite the use of two different constructs, the directions of the associations were similar. A further strength of the intervention was the community co-creation process to actively engage local community and stakeholders at all stages in the process. This process helped to ensure that the renovations met their needs and wishes (Hunter et al., 2019; Ward Thompson et al., 2019).

Nevertheless, we recognise several important limitations, which means the results need to be interpreted with some caution. First, the most obvious limitation is the lack of a control group. Due to the real-life setting, there may have been uncontrollable sources of error in our estimates, such that pre-post intervention differences may have been due to other factors not associated with the intervention e.g. different average weather conditions, or economic or political developments across the 12-month sampling period. In Plymouth, comparable blue spaces with similar surrounding populations were not identified, and even if such scenarios existed, financial resources for parallel evaluation were lacking. We acknowledge that future work on similar urban blue space intervention projects is needed to establish the external validity of the findings presented here.

Second, the repeat cross-sectional design limits the ability to draw causal conclusions. The pre- and post-intervention samples had notable differences in individual characteristics. This may suggest that we included two completely different samples at pre-test or post-test, or perhaps that over the course of a year the characteristics of the target population had changed, despite the relative stability of residential status due to the predominance of social housing in the target area. Because we can only speculate about the reasons for the differences between the two samples, associations were adjusted for a large number of potential confounder variables. Adding the potential confounders improved the explained variance in the models, and associations with and without respondents with missing data were comparable. Nevertheless, we recommend that future work include – if feasible – a within-person design where the same respondents respond to both pre- and post-intervention measurements (although this can have issues of its own in terms of demand characteristics and non-random dropout). Future work can further enhance research methods by including longer-term follow-up measurements to investigate if associations hold over the longer-term.

Third, because of poorer doorstep recruitment than we hoped, we were worried about lack of power and therefore extended recruitment to the outdoor local neighbourhood. Although the guided interview with show-cards was the same for both methods, the difference in approach may have introduced systematic bias in the results, for example by recruiting more people who had visited the site recently in the neighbourhood vs. doorstep sample. Moreover, although the site was directly visible for some of the homes we approached in the doorstep method; it is likely that the site was more often visible for those recruited through the neighbourhood method, many of whom were approached on the East-West path at the North of the site. Being able to see the site at the point of being interviewed may well have affected responses. Nevertheless, sensitivity analyses suggested that particularly among people who were recruited with the doorstep method (i.e. the sample we initially intended to target), post-intervention positive well-being was higher than pre-intervention. In this sample, life satisfaction was also higher post-intervention than pre-intervention, but the confidence intervals were wide and the association seemed to be marginally stronger for those recruited with the neighbourhood method. Although these findings support our confidence that the intervention was indeed beneficial for those whom it was intended for, we remain cautious about over-interpreting the results. Future studies may want to think carefully about how they will recruit enough participants within a small surrounding area using just a single sampling method.

Finally, we were unable to tease apart the relative importance of the physical infrastructure aspect of the intervention and the social aspects of the intervention in order to understand their respective roles. We suspect however, that at least in the short-term (i.e. as long as the local community engaged in the process continues to live in the area), the separation of these components would to some extent be artificial and that their very integration is what makes a project successful. Further work, in other sites, at other scales, and using other evaluation methods, are needed to explore the relative importance of the landscape design and the community engagement. For example, also incorporating longer term follow-up measurements may also provide insight as to whether higher well-being was reported merely due to environmental improvements or due to other factors such as – for example - continued community engagement. Nonetheless, we contend that our post-test measurement period (4 months after the completion of the intervention) would have left sufficient time for novelty effects to dissipate.

4.2. Conclusion

The present study explored if a blue space-specific co-created intervention in a deprived urban area was associated with psychological well-being among local residents and people visiting the local neighbourhood. Relatively small, but carefully targeted improvements to an urban beach area in Plymouth, UK were associated with higher levels of psychological well-being after the intervention, although causality could not be guaranteed. Given that associations may be stronger for those who regularly visit the site, planners may want to give greater weight to considerations on how to support recreational visits as opposed to improvements in environmental quality alone. We would also recommend that blue space interventions are co-created with their

local communities and are accompanied by social programmes in order to facilitate the potential benefits. Although preliminary, findings of this present study may help guide the design process of future co-created blue space interventions.

Financial support

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 666773. The first author received funding from Amsterdam Public Health Research Institute, Health Behaviours & Chronic Disease (HBCD) Programme Travel Grant (grant number V.2018.009/MdB/Edb) and the Erasmus + Student Traineeship Grant. The site redesign, which is the focus of this study, also received funding from the UK National Lottery's Big Lottery Fund as part of Plymouth City Council's Active Neighbourhoods programme.

CRediT authorship contribution statement

Nicole van den Bogerd: Formal analysis, Writing - original draft. **Lewis R. Elliott:** Conceptualization, Methodology, Investigation, Resources, Data curation, Supervision, Writing - review & editing. **Mathew P. White:** Conceptualization, Methodology, Investigation, Supervision, Funding acquisition, Project administration, Writing - review & editing. **Himansu S. Mishra:** Conceptualization, Methodology, Investigation. **Simon Bell:** Conceptualization, Methodology, Investigation, Funding acquisition. **Miriam Porter:** Investigation. **Zoë Sydenham:** Writing - review & editing. **Joanne K. Garrett:** Writing - review & editing. **Lora E. Fleming:** Conceptualization, Methodology, Funding acquisition, Supervision, Writing - review & editing.

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.

Acknowledgements

We would like to thank Chris Bowden and his colleagues at Marketing Means for collecting the data that were used in this study. We also thank residents of Teats Hill and members of the project management group including Ashley Tod, Tim Russell, Hazel Alexander, Guy Baker, Eliane Bastos, Nikki Bickford, Liz Cole, Leigh Cooper, Deborah Cracknell, Kaja Curry, Cllr Sue Dann, Mark Duchense, Louise Firth, Sarah Gibson, Mike Goble, Caroline Hattam, Colin Johnson, Laura Larkin, Marissa Maloney, Kate McGarry, Andrew Pitcher, Chris Price, Jack Sewell, Kieran Shaw-Flach, Rebecca Shellock, Adam Thomas, Richard Thompson, Heidi Tillin, Neil Worth, Nicola Murray, John Readman, Helen Nance, and Beth Siddon.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2021.104232.

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