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Theory-based design for promoting positive behaviours in an urban blue space: Pre-and-post observations of a community co-created intervention in Plymouth, United Kingdom

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HIGHLIGHTS

- A pre-post behaviour observation mapping study was conducted using a co-created small-scale blue space intervention.
- Post-intervention, the use of the intervention and the neighbouring non-intervention area both increased.
- Post-intervention, the odds of standing, visitors being women or in a group were higher in the intervention area.
- Post-intervention, the odds of viewing were higher across the site.

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ABSTRACT

Behaviour observation and mapping are useful planning tools to generate evidence to create people-friendly public spaces. Small-scale interventions are gaining popularity as cost-effective and quick solutions to regenerate degraded urban outdoor environments. Onsite behaviour observation mapping with GIS underpins evidence gathering, analysis, and planning and design decision-making. Using the BlueHealth Behaviour Assessment Tool (BBAT) developed within the EU-funded Horizon 2020 Project "Blue Health", we carried out pre- and post-intervention observations of visits, activities and visitors' characteristics in a site at Teats Hill, Plymouth, United Kingdom. Pre-post comparison of visits and activities in three target areas the entire site before and the within-site intervention area (a small open-air theatre) and the rest of the site afterwards were examined to analyse the impact of the intervention on socialising and relaxing activities. Behaviour observation data was both spatially and statistically analysed. Key outcomes were sitting, standing, walking, activity with a dog, viewing, using a phone and socialising. Both a logistic regression model and spatial analysis using density maps and hot spot analysis confirmed an increased use of the open-air theatre and its positive impact on the use of the rest of the park (the non-intervention area). Our logit models showed that the intervention promoted positive behaviour for health (i.e. blue space activities, socialisation, and relaxing activities), greater inclusivity and diversity of visitors. We conclude that an evidence-based design approach can increase blue space accessibility, improve place affordances and promote positive behaviour and psychological well-being benefitting local communities.

1. Introduction

Landscape elements can directly influence the presence and distribution of people, their use patterns and range of activities (Goličnik Marušić, 2016; Gehl, 2011) at a site. Landscape design interventions can thus alter the number or type of people who visit, their activities, and/or their perceptions (e.g. safety) about the space (Hunter et al., 2015, 2019). In order to understand how a design intervention affects such patterns and behaviours, it is necessary to monitor systematically how the space is used both before and after changes occur (Marušić, 2015).

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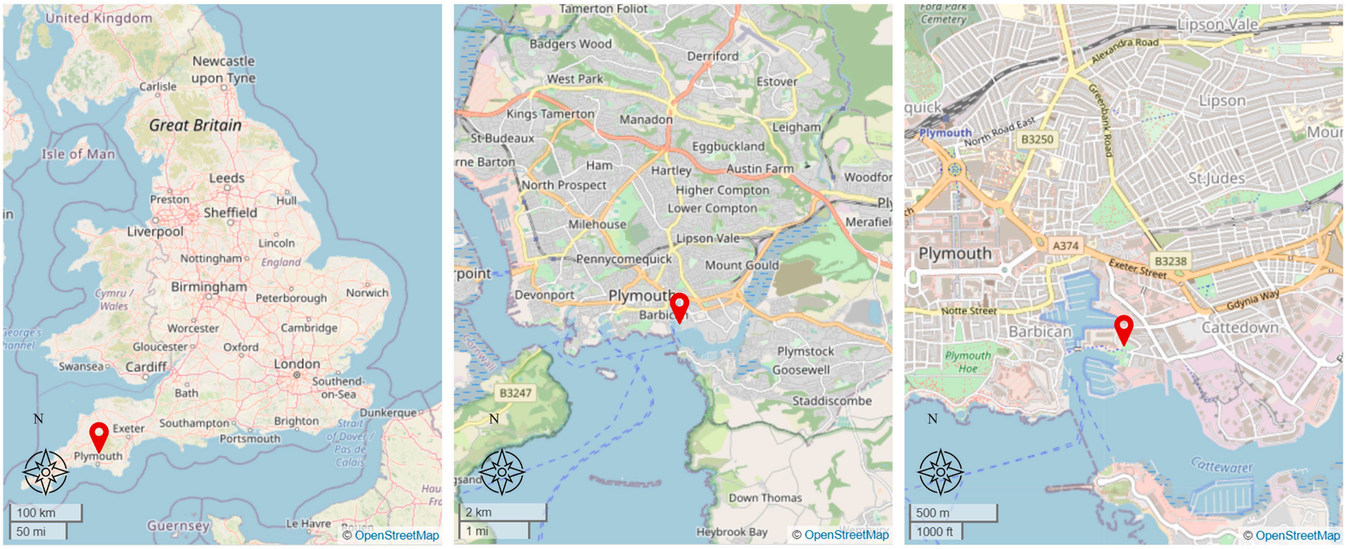


Fig. 1. Location of Teats Hill, Plymouth, UK. Source: © OpenStreetMap: data is licensed under the Open Data Commons Open Database License (ODbL).

This allows us to make an evidence-informed assessment about whether or not the changes achieved their objectives (e.g. to create a safe space for a broader section of the local community to meet and socialise), and in turn inform evidence-based design practices (Hunter et al., 2015).

Given the growing body of evidence that access to and recreational use of blue spaces, such as rivers, lakes, and shorelines, may be particularly supportive of individual and population-level health and well-being outcomes (White et al., 2020), sensitive, community-engaged small-scale redevelopment of a site could potentially have profound impacts on a local community. The current paper contributes to the momentum of evidence-based design by presenting results from a relatively small, but potentially powerful, landscape intervention at Teats Hill Park located in a deprived urban area of Plymouth in South West England. (Fig. 1; Supplementary material C). Many of the technical aspects and results of a pre-post community survey about the intervention have already been published (van den Bogerd et al., 2021). Here, we present data about how the space was used, and by whom, over two, twelve-week, season-matched periods before and after the intervention. Behavioural data is particularly important for evidence-based design, because how people behave, as opposed to their stated satisfaction with a place, is likely to be directly associated with key health and well-being outcomes (e.g. engagement in health promoting physical activities). As well as being of relevance to this specific case study site, our results have broader implications since, compared with green spaces, blue spaces have been far less studied in terms of their health and well-being benefits (Völker & Kistemann, 2015; Vert et al., 2019), and the application of behavioural observation and mapping techniques to uncover the relationship between spatial properties and health-promoting activities remains relatively scarce (Unt & Bell, 2014; Vert et al., 2019). Despite growing evidence linking exposure to blue spaces and health benefits to space aspects, such as place quality, and user characteristics (White et al., 2020), knowledge is scarce about what features of blue spaces mattered for these outcomes and what calls for a greater understanding of how and why blue spaces seem to be so important.

By deliberately designing and testing a blue space intervention (Bell et al., 2020) based on theories of behaviour settings (Barker, 1963) and place affordances (Heft, 2010), and monitoring use behaviours through systematic observation (Goličnik Marušić, 2011), the current work provides one way of obtaining demonstrative evidence of its health potential through actualised health-promoting behaviours and thus addresses the identified lacuna in evidence.

1.1. Theory of behaviour setting and affordance.

A behaviour setting is an ecological construct of an environment that exists at the intersection between the standing patterns of human behaviour and the socio-physical domain of that environment (Cosco et al., 2010; Cushing & Pennings, 2017). These ecological settings support different human behaviours and provide psychological, personal and social experiences, the place-based aspect of activities being functions of the environmental condition and quality (Ward Thompson, 2013). For example, the design of an outdoor behaviour settings (such as a promenade) provides visitors with cues about different use possibilities (Cushing & Pennings, 2017). Place-based activities are a function of the environmental condition and quality aspects of the place e.g. aesthetic quality (Ward Thompson, 2013) which are subject to variations in case of different urban blue space settings (Mishra et al., 2021).

An affordance (Gibson, 1977; Norman, 1988; Heft, 2010) is a theoretical construct manifests the transactional relationship between the user characteristics and cognition, and the properties of the place or an object in use (Townshend & Roberts, 2013). Affordances are inherent to the environment (Kyttä, 2002) which is perceived i.e. visually and being aware of the affordance through perceptions (Norman, 1988) and actualised through potential actions (i.e. physical) (Gibson, 1979). Perceptive environmental affordances in public spaces are shaped positively and negatively in the presence of people or activities occurring (Whyte 1980). The perceptible functional properties of the place trigger psychological or behavioural responses (Townshend & Roberts, 2013), which allows an individual to be aware of the opportunities available for a possible physical engagement with the space or an object (Norman, 1988). For example, just by knowing that a beach is available within a walkable distance increases possibilities to visit it, whereas the access to the beach, perceived beach culture, quality and safety aspects, or the beach infrastructure in place determine the possibilities of actions and activities occurring. Furthermore, while physical affordances with functionally significant properties of an outdoor environment (i.e. action) are apparent among children for activities independent of their appearance (Heft, 1988; Niklasson & Sandberg, 2010; Kyttä, 2002), in addition to the functional properties, form (Heft, 1988), pleasure, beauty, meaning and attractiveness of place (Grahn & Stigsdotter, 2010; Heft, 2010), place design quality and attributes linking needs and intentions (Hadavi et al., 2015) matter to grown-ups.

1.2. Physical interventions, place quality and characteristics for health-promoting activities

Physical interventions inserted into an existing environment may include an area- or function-specific improvement, for example, the refurbishment of a play area or improved seating, which influence place usage (Veitch et al., 2012) by attracting more children or older, less mobile adults respectively. Positive effects of intervention sites on health-promoting behaviours compared to controlled non-intervention sites have been tested and demonstrated (Cohen et al., 2015; Vert et al., 2019). While research has focused on the effects of physical interventions in parks, woodlands and trails (Benton et al., 2021; Hunter et al., 2019), blue space interventions and health benefits have been much less studied (Vert et al., 2019). Moreover, when co-designed with local stakeholders and communities based on evidence, places offer greater user relevance for the design outcomes and tend to lead to increased possibilities of actualising intended affordances as well as some additional ones (Hunter et al., 2019; Refshauge et al., 2015).

1.3. Behaviour observation and mapping

Behaviour observation and mapping is an on-site assessment technique that objectively links place affordances with behaviour settings (Ward Thompson, 2013). Observational studies have long been linked to mapping to understand visual and aesthetic properties of public spaces (Lynch, 1960). They have moved on to test how space characteristics support (Gehl, 2011) or impact (Ward Thompson & Aspinall, 2011) user behaviour in a specific setting rather than generally across a site (Unt & Bell, 2014). As a direct, in-situ, non-participatory method (Moore & Cosco, 2010), behaviour observation captures space use and occupancy patterns and densities (Goličnik Marušić, 2011; Sun et al., 2022). Moreover, mapping and analysis of activities can compare an intervention with a non-intervention site or between pre-and-post-intervention periods of a single site (Goličnik Marušić, 2016; Vert et al., 2019).

1.4. The present study and the intervention

The current study used a pre-post design to test the impact of a small-scale designed physical intervention at an historical urban coastal blue space at Teats Hill, Plymouth, UK (Supplementary material A-i) by comparing the overall use frequency, type of user and activities carried out in different behaviour settings within the overall site (Fig. 1). The intervention project was a collaboration between Plymouth City Council's Active Neighbourhood Project, 2016 and the European Union-funded Horizon 2020 Project "BlueHealth".

The study site could be divided into five sub-areas: a) access path to and through the site, b) the park, c) the upper slip road, d) the lower slip road, e) and the water interface (including a beach and tidal shoreline) (Fig. 2; Supplementary material A-ii). Importantly, the intervention - reported in detail elsewhere (Bell et al., 2020, Külvik et al., 2021) (see Fig. 2; Supplementary material A-iii) focused only on changing features of: a) the lower slip road and beach access; and b) specific aspects of the park, providing us with the opportunity to compare behaviours in areas of the site where we had intervened with areas of the site where we had not. This quasi-controlled aspect to the study was important because, following discussion with the local council, there was no comparable control site in the city where we could simply monitor behaviour without any intervention. The project did not aim at a complete make-over of the existing site but adopted a well-established approach to the design and planning of urban interventions, that of "urban acupuncture" concept, which targets specific key aspects of a site (Casagrande, 2019). Stakeholder meetings and public engagement events informed the co-creation of the blue space intervention.

Improving access to the beach aimed to support and promote water-based activities (e.g. swimming and canoeing) and time spent walking, standing, sitting and viewing and relaxing on the shoreline, all of which have been found to enhance health and well-being outcomes (e.g. Britton et al., 2020). The seaward-facing open-air theatre with seats arranged in a semi-circle was designed to facilitate recreation and encourage social interactions, which have also been found to be a key feature of blue spaces promoting mental health and well-being among children and families (Ashbullby et al., 2013), even relative to otherwise comparable green spaces (Bell et al., 2015; Völker & Kistemann, 2015). The developments of the play area aimed to encourage greater use by families and children, and also provided a safe space where every-one would be welcome (Kaźmierczak, 2013; Peters et al., 2010). Although we agreed to not observe this area directly, for ethical reasons, we nonetheless predicted that these improvements would increase the number of families with small children visiting the overall site.

Our specific hypotheses were, thus, that comparing pre-post observations, the intervention would lead to:

(H1) greater total numbers of visitors to the site, in particular to the key target areas of H1a) the site (Teats Hill); H1b) the intervention area (the open-air theatre and water interface area), and H1c) the non-intervention area (the rest of the park including the access path).
(H2) greater numbers of people directly engaging in positive behaviours for health and well-being including: H2a) water-based activities in or by the water; H2b) socialising activities, especially around the purpose-designed open-air theatre; H2c) sitting and relaxing, reflecting comfort and feelings of safety (as opposed to merely passing through).
(H3) greater inclusivity and diversity of site visitors, reflecting perceived safety and positive affordances, resulting in higher numbers of: H3a) women; H3b) children and teenagers; H3c) older adults.

2. Materials and methods

2.1. Site selection

The site, Teats Hill in Plymouth, UK (Fig. 1), a public green and blue space, was identified for the intervention for several reasons:

- high cultural, historical and local significance,
- deterioration in the quality of blue space infrastructure,
- area social deprivation status and
- direct access to the foreshore (intertidal zone),

The site is located along a busy pedestrian and cycle access path within a community. The densification of the surrounding area of Teats Hill, the construction of a marina and the abandonment of an old slipway made the site less usable. A lack of investment in facilities and overgrowing vegetation also led to a run-down atmosphere and illegal and anti-social behaviour. As a result, the site lacked place quality and community identity and offered visitors a less attractive outdoor destination with few affordances for recreation.

2.2. Behaviour mapping protocol

We adopted a longitudinal behaviour observation and mapping method and examined the potential of the intervention for physical and social activities. We used an established behaviour observation mapping technique (Goličnik Marušić, 2011, 2016; Unt & Bell, 2014; Moore & Cosco, 2010). Full details of methods can be found in Supplementary material B, which outlines how we went beyond the existing practice of a paper-based method and adopted a GIS-based approach (Goličnik Marušić, 2011; Ghavampour et al., 2017) which we developed as the BlueHealth Behaviour Assessment Tool (BBAT) within the BlueHealth project – https://bluehealth.tools/ (Vassiljev et al., 2021). The BBAT uses the Quantum GIS (QGIS) platform for the data collection (QGIS

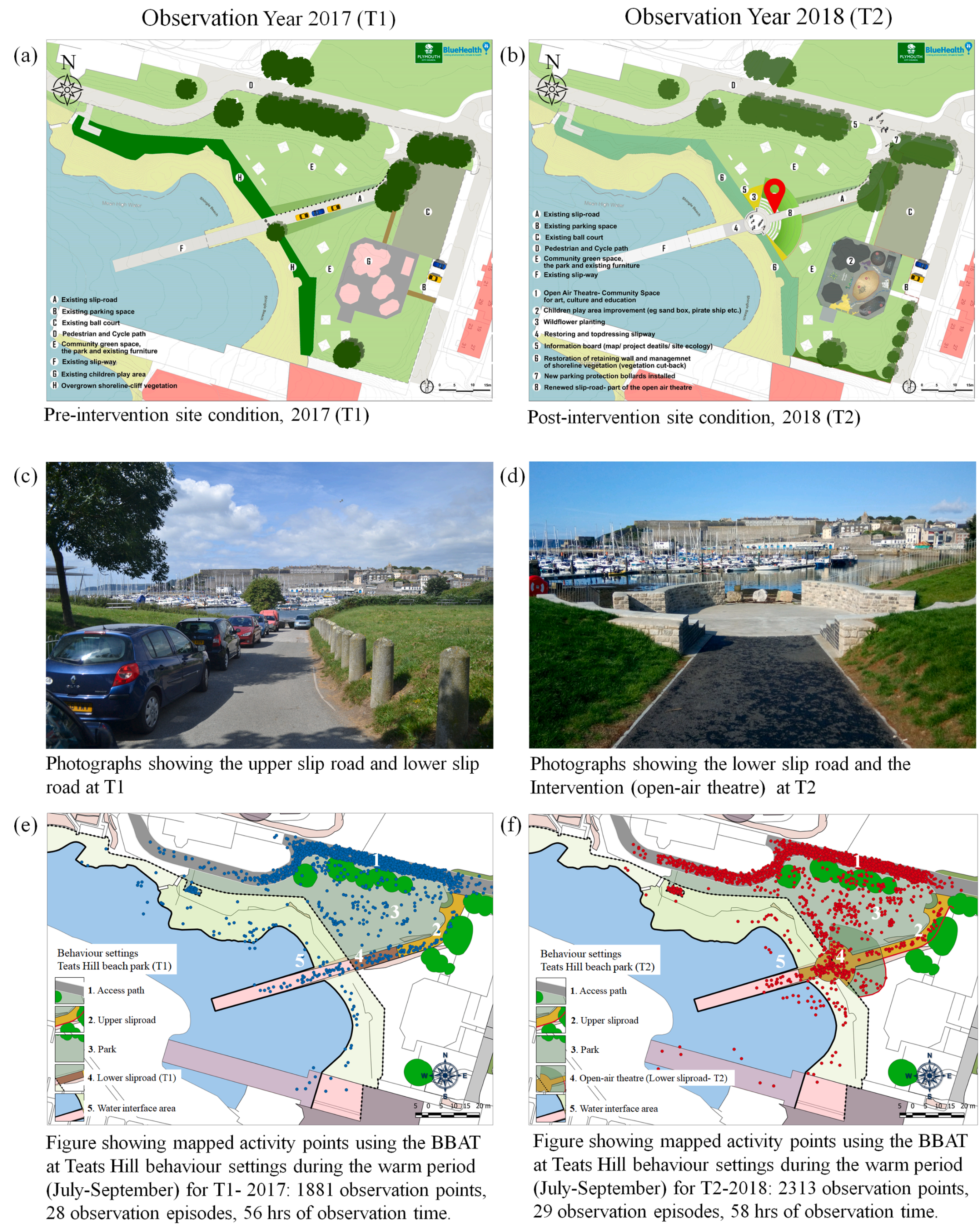


Fig. 2. Plans and photographs showing site conditions pre and post-intervention in Teats Hill, Plymouth, UK (Source: authors).

Development Team, 2016, v 3.2.3; https://qgis.org/en/site/forusers/download.html) on a tablet computer. This tool features a drop-down menu for observers to identify and record details of users and activities (see Section 2.3) and to place an accurate marker of the spot where these were observed within the sampling period.

The data collection process was carried out by trained observers according to a specific protocol to sample all times of day (during daylight hours) and days of the week over the 12-week sampling periods from June-September 2017 (pre-intervention) and 2018 (post-intervention). The sampling period was deliberately matched for seasonality. The renovations of the areas occurred between February and May 2018.

2.3. Variables of interest

Using the BBAT methodology, sampled individuals were assigned codes for: a) where they were at the time of observation (location, see H1); b) the behaviours they undertook (see H2); and c) main socio-demographic characteristics (see H3). Because locations and activities may be influenced by factors not associated with the intervention, we also measured potential confounders such as d) visitor group structure; e) the time and day of the week (temporal aspects); and f) weather conditions (fair/rain).

2.3.1. Location

Our main predictor variable was location. As noted above, the site was divided into five behaviour settings: the access path, upper slip road, the park, lower slip road-T1 (which became the open-air theatre at T2), and the water interface area (i.e. natural cliff area, edge of the water, slipways, open water low tide). We refer to the entire study area as "the site". We refer to the upper slip road and park as the "non-intervention area" and the lower slip road (T1)/ open-air theatre (T2) and the water interface area as the "intervention area". Setting was our main predictor variable used to predict the presence of (H1) and behaviours by (H2) individual park visitors pre-post intervention.

2.3.2. Behaviours

Behaviours were our main outcome variable for H2 and were categorised into primary activities – how a person was physically interacting with the environment – such as "walking", "cycling", "sitting", "water activities", and "dog-related activities", and secondary activities - co-activities occurring as part of primary activities - such as "socialising", "use of phone" and "observing the view". A full list of all behaviours is presented in Supplementary material C, but due to low numbers of some behaviours, selected activities were grouped into broader categories of similar behaviours for analysis. For instance, ballgames, frisbee, informal games etc., were simply collapsed into "outdoor play" (Supplementary material C). This left nine-primary and six secondary activities.

2.3.3. Visitor characteristics (inclusivity)

To explore visitor diversity and inclusivity (H3), we estimated people's gender (male/female) and age (four groups): children (0–12 yrs), teenagers (13–19 yrs), adults (20–59 yrs) and older adults (above 60 yrs). Some misclassification may have occurred for both of these variables. We excluded data on ethnic background due to the limitation of identifying ethnicity solely by the visual observation method (BBAT), especially given the UK categorisation system (https://www.ethnicity-facts-figures.service.gov.uk/style-guide/ethnic-groups).

2.3.4. Potential confounders

To account for the fact that people may visit different parts of the site and engage in different activities depending on who they were visiting with, we also recorded whether they were alone, in a pair, or in a group (>2 individuals). To account for the fact that location and activity may change due to temporal factors we measured time of day ("morning", "lunchtime", "afternoon", "evening") and time of the week ("weekday", "weekend"). Finally, to account for the influence of weather conditions we also recorded temperature (°C); and "no rain" vs "some rain". Temperature data for each observation period of the day was collected using a smartphone application. The data on cloud and rain condition was collected through visual inspection and reported using a set of pre-defined weather categories.

2.4. Data analysis

2.4.1. Quantitative analysis

To test our three hypotheses formally, we ran a number of linear regressions to understand a) where individuals were (H1), b) what they were doing (H2), and c) who they were with (H3). Variables included in the models were location; survey year: T1 (ref) vs T2; site location: intervention area vs non-intervention area (ref); site users: gender- male (ref) vs female, age group- children, teenagers, adults (ref), older adults, group structure- alone (ref), in pairs, in a group); temporal: time of day- morning, afternoon, lunchtime, evening (ref), time of week: weekday (ref) vs weekend; and weather: temperature (°C), rain: no rain (ref) vs rain.

Analysis was performed using the statistical software R (Version 4.1.1; R Core Team, 2021). For H2 and H3 mixed effects, logistic regression was performed using the default logit link, as the outcome variables were binary. The goodness of fit for all models was assessed using model residuals and AIC.

For H2, we ran eight Binomial models to explore (i) primary activities: sitting, standing, walking, and activities with a dog and ii) secondary activities: viewing, socialising and using a phone. For these models, the access path was excluded since the high numbers of observations along it skewed the results for site location. Therefore, for these models, there were 411 observations in 2017 and 713 in 2018. Covariates included in these models were survey year, site location, site users, temporal and weather variables and an interaction between survey year and site location. Observation episode was included as a random variable (with 28 episodes in 2017 and 29 in 2018). Model estimates were back-transformed from the logit scale for reporting.

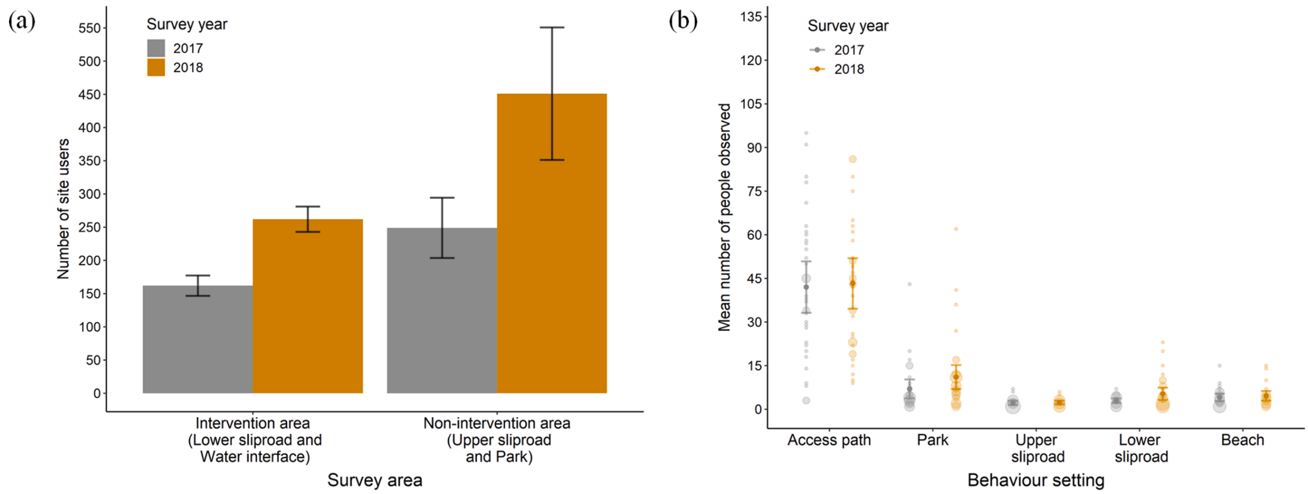
Finally, for H3 we ran eight Binomial models and were interested in factors associated with inclusivity: age, gender and group structure. Models included survey year, site location, site users, temporal and weather condition variables and an interaction between survey year and site location. Observation episode was included as a random variable. These models had the same number of observations and observation episodes as those for H2. For the gender model, the response was males (0) and females (1); these models did not include gender as a covariate. For the age group and group structure models, each category was compared to all others, for example children (1) were compared to adults, teenagers and older adults (0). Age group was not included as a covariate for the age group models and group structure was not included for the group structure models. Model estimates were transformed into Odds Ratios for reporting.

2.4.2. Spatial analysis

The objective of the spatial analysis is twofold. Firstly, to capture the occurrence of different behaviour patterns, and secondly, to visualise the overall spatial distribution patterns and density of the activity points by variables including gender, age group, time of visit, and different behaviour settings. The spatial analysis explained specific locations of interest related to the behaviour settings. Heat mapping and hot and cold spot analyses were used to show a) density distribution, clustering of activities and the spatial significance of activities and b) the spatial clustering of meaningful concentrations of activity points compared to a random distribution of the points, respectively (Dempsey, 2014).

Table 1
Description of Teats Hill blue space attributes observed during the warm period (July to September) for the study area, non-intervention area, intervention areas.

			The study area (including the access path)			The study area (excluding the access path)					
						Intervention area (lower slip road/ open-air theatre and water interface area)			Non-intervention area (park and upper slip road)		
			2017 (T1)	2018 (T2)		2017 (T1)	2018 (T2)		2017 (T1)	2018 (T2)	
	Blue space attributes were observed during the warm period (July to September).	Nos.	Nos.	% Change	Nos.	Nos.	% Change	Nos.	Nos.	% Change	
(a)	**Total number of visits/ activities**	1881	2313	**22.97**	162	262	61.73	249	451	81.12	
(b)	**Location**										
		Intervention area	56.00	165.00	**194.64**	–	–		–	–	
		Non-intervention area	1825.00	2148.00	**17.70**	–	–		–	–	
	Behaviour setting	Access path	1470.00	1600.00	**8.84**	–	–		–	–	
		Park	203.00	409.00	**101.48**	–	–		–	–	
		Upper slip road	46.00	42.00	**−8.70**	–	–		–	–	
		Lower slip road (T1)/ Open-air theatre (T2)	56.00	165.00	**194.64**	–	–		–	–	
		Water interface area	106.00	97.00	**−8.49**	–	–		–	–	
(c)	**Behaviour**										
	Primary activities	Activity with a dog	246.00	222.00	**−9.76**	33.00	23.00	**−30.30**	48.00	67.00	**39.58**
		Cycling	116.00	198.00	**70.69**	1.00	3.00	**200.00**	5.00	9.00	**80.00**
		Jogging	26.00	43.00	**65.38**	1.00	0.00	–	0.00	4.00	–
		Outdoor play	65.00	52.00	**−20.00**	12.00	22.00	**83.33**	21.00	23.00	**9.52**
		Sitting	113.00	308.00	**172.57**	32.00	74.00	**131.25**	80.00	230.00	**187.50**
		Standing	142.00	203.00	**42.96**	52.00	99.00	**90.38**	58.00	76.00	**31.03**
		Walking	1163.00	1268.00	**9.03**	21.00	22.00	**4.76**	37.00	42.00	**13.51**
		Water activities	10.00	19.00	**90.00**	10.00	20.00	**100.00**	0.00	0.00	–
	Secondary activities	Resting and relaxing	42.00	54.00	**28.57**	16.00	14.00	**−12.50**	20.00	31.00	**55.00**
		Socialising	892.00	1050.00	**17.71**	65.00	118.00	**81.54**	108.00	223.00	**106.48**
		Use of phone	128.00	114.00	**−10.94**	17.00	21.00	**23.53**	24.00	33.00	**37.50**
		Refreshment (eating and drinking)	29.00	58.00	**100.00**	2.00	17.00	**750.00**	21.00	37.00	**76.19**
		Viewing	212.00	771.00	**263.68**	42.00	121.00	**188.10**	66.00	203.00	**207.58**
		Using baby pram	51.00	72.00	**41.18**	0.00	1.00	–	1.00	4.00	**300.00**
(d)	**Visitor characteristics (inclusivity)**										
	Gender	Men	1024.00	1256.00	**22.66**	120.00	137.00	**14.17**	139.00	239.00	**71.94**
		Women	857.00	1057.00	**23.34**	43.00	126.00	**193.02**	110.00	212.00	**92.73**
	Age group	Children	199.00	252.00	**26.63**	19.00	30.00	**57.89**	35.00	54.00	**54.29**
		Teenagers	208.00	249.00	**19.71**	20.00	67.00	**235.00**	31.00	80.00	**158.06**
		Adults	1198.00	1441.00	**20.28**	119.00	116.00	**−2.52**	154.00	255.00	**65.58**
		Older adults	276.00	371.00	**34.42**	4.00	24.00	**500.00**	29.00	62.00	**113.79**
	Group structure	Alone	652.00	751.00	**15.18**	73.00	62.00	**−15.07**	95.00	149.00	**56.84**
		In-pairs	605.00	808.00	**33.55**	48.00	80.00	**66.67**	58.00	144.00	**148.28**
		In a group	624.00	754.00	**20.83**	41.00	120.00	**192.68**	96.00	158.00	**64.58**
(e)	**Potential confounders**										
	Temporal aspects	Weekday	1368.00	1611.00	**17.76**	117.00	180.00	**53.85**	156.00	339.00	**117.31**
		Weekend	513.00	702.00	**36.84**	45.00	82.00	**82.22**	93.00	112.00	**20.43**
		Morning	420.00	178.00	**−57.62**	37.00	8.00	**−78.38**	57.00	31.00	**−45.61**
		Lunchtime	572.00	835.00	**45.98**	44.00	95.00	**115.91**	104.00	170.00	**63.46**
		Afternoon	576.00	946.00	**64.24**	38.00	113.00	**197.37**	46.00	147.00	**219.57**
		Evening	313.00	354.00	**13.10**	43.00	47.00	**9.30**	42.00	103.00	**145.24**
	Cloud condition	No cloud	452.00	1036.00	**129.20**	52.00	102.00	**96.15**	89.00	192.00	**115.73**
		Cloudy	1429.00	1156.00	**−19.10**	110.00	122.00	**10.91**	160.00	218.00	**36.25**
		Unknown	0.00	121.00	–	0.00	38.00	–	0.00	41.00	–
	Precipitation	No rain	1501.00	2247.00	**49.70**	134.00	254.00	**89.55**	216.00	437.00	**102.31**
		Some rain	380.00	66.00	**−82.63**	28.00	8.00	**−71.43**	34.00	14.00	**−58.82**
	Wind condition	No wind-calm winds	1698.00	2235.00	**31.63**	142.00	248.00	**74.65**	222.00	442.00	**99.10**
		Strong winds	183.00	78.00	−57.38	20.00	14.00	**−30.00**	27.00	9.00	**−66.67**



The difference between the number of users in the intervention (lower slip road in T1/ open-air theatre in T2 and water interface area) and non-intervention area (upper slip road and the park) between 2017 and 2018.

The mean number of observations across different behaviour settings at Teat Hill between 2017 and 2018.

Fig. 3. Graphs comparing distribution of visitors across intervention and non-intervention area and different behaviour settings at T1 and T2.

For heat mapping, the Kernel Density efficiently identifies the spatial significance of an event or geographic clustering of a phenomenon (Hart & Zandbergen, 2014). Moreover, using QGIS has been proven effective in studies analysing relationships between space configuration and user behaviour via mapping techniques (Sun et al., 2022). Thus, we used Kernel Density estimation to visualise the spatial density of mapped blue space activities at the site (Netek et al., 2018) and used 4 m search radius with output cell size of 1 m for smooth heat maps. As a result, the heat maps demonstrate interpolated surfaces of the density of the occurrence. Hot/cold spot maps statistically differentiate the areas of high from low occurrence areas and are less subjective compared to heat maps. Hot and cold spot analysis of activity data is a valuable method for assessing the significance and the embedded meaning of data clustering (Resch et al., 2020). We conducted heat map analysis using QGIS (QGIS Development Team, 2016) and hot spot analysis using ArcGIS desktop 10.6 (Esri, 2017).

2.4.3. Survey data

For the quantitative analysis we created two observation datasets (see Table 1) based on location (i) the site (including the access path) (H1) and (ii) the site excluding the access path (H2, H3). For spatial analysis (heat maps), we used the first dataset to show the overall dispersion of visitors at the site, emerging patterns, and the differences in trends between T1 and T2 for accessibility and the use of different behaviour settings. For the hotspot analysis, we used the second dataset to demonstrate the effect of the intervention on blue space use and activities.

2.4.4. Random variables

Observation period: Due to some observations being conducted on the same day, but at different times of day, we class an observation period as observations carried out on a specific day at a specific time of day, e.g. Day 14, Afternoon. The observation period was included in all models as a random intercept to account for sampling design.

3. Results

We present the results according to the two main analysis methods. Results demonstrate the spatial patterns and compare changes between T1 (pre-intervention, 2017) and T2 (post-intervention, 2018) and evaluate the impact of the intervention, i.e. the presence of (H1), behaviours by (H2), and diversity and inclusivity (H3) of park visitors pre-post intervention. The total observation sample collected for (i) the site (i.e. Teats Hill, including both intervention and non-intervention areas and the access path) in T1 was N = 1881, and T2 was N = 2313; two sub-site areas (ii) the intervention area in T1 was N = 162 and in T2 was N = 262, and (iii) for the non-intervention area in T1 was N = 249 and in T2 was N = 451 (Table 1).

3.1. Pre- and post-intervention differences in greater total number of visitors to the site, particularly the key target areas (H1)

3.1.1. The site (H1a)

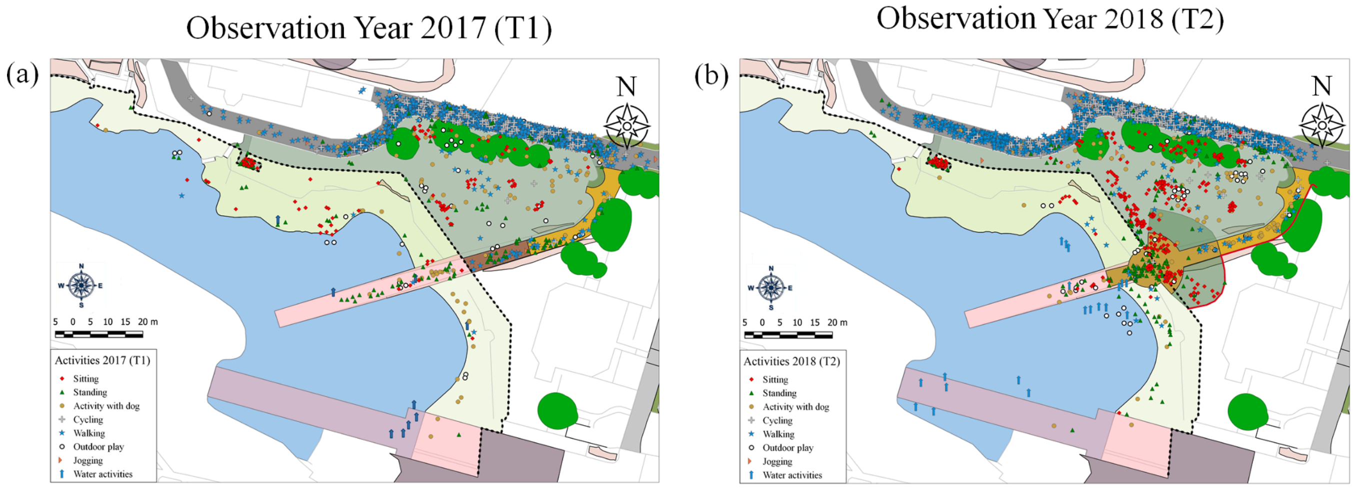
At T2 total visits to the site (including the access path), the intervention area, and the non-intervention area increased by 22.97 %, 61.73 %, and 81.12 %, respectively (Table 1; Fig. 3a). Visits especially increased in the park (101.48 %) and the open-air theatre (194.64 %) (Fig. 3b). The access path was well used in both years (1470 and 1600 visitors respectively). At T2, weekend, lunchtime and afternoon visits increased by 36.84 %, 45.98 % and 64.24 %, respectively. These result partly supports H1a that at Teats Hill, the total number of visits increased post-intervention.

3.1.2. The intervention area (H1b)

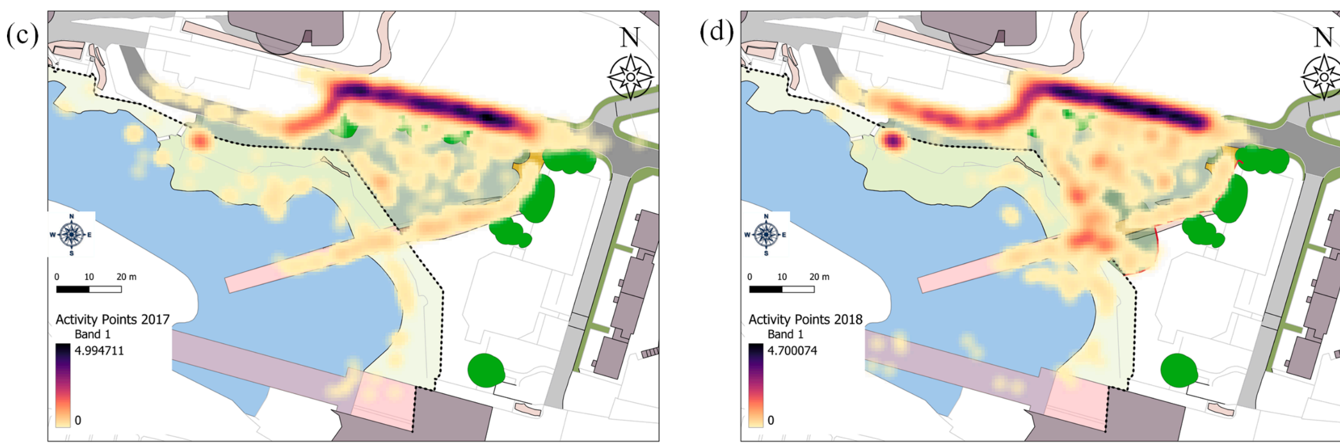
At T2 in the intervention area, total visits increased by 61.73 %. At the lower slip road (i.e. the open-air theatre at T2), visits increased by 194.64 %, whereas visits declined (-8.49 %) in the water interface areas (the beach areas). Moreover, weekend, lunchtime, and afternoon visits to the intervention area increased by 82.22 %, 115.91 %, and 197.37 %, respectively, at T2. Supporting H1b, these results are reflected in Fig. 3a, which show a high concentration of visitors at the open-air theatre, demonstrating that the intervention attracted more visitors at T2.

3.1.3. The non-intervention area (H1c)

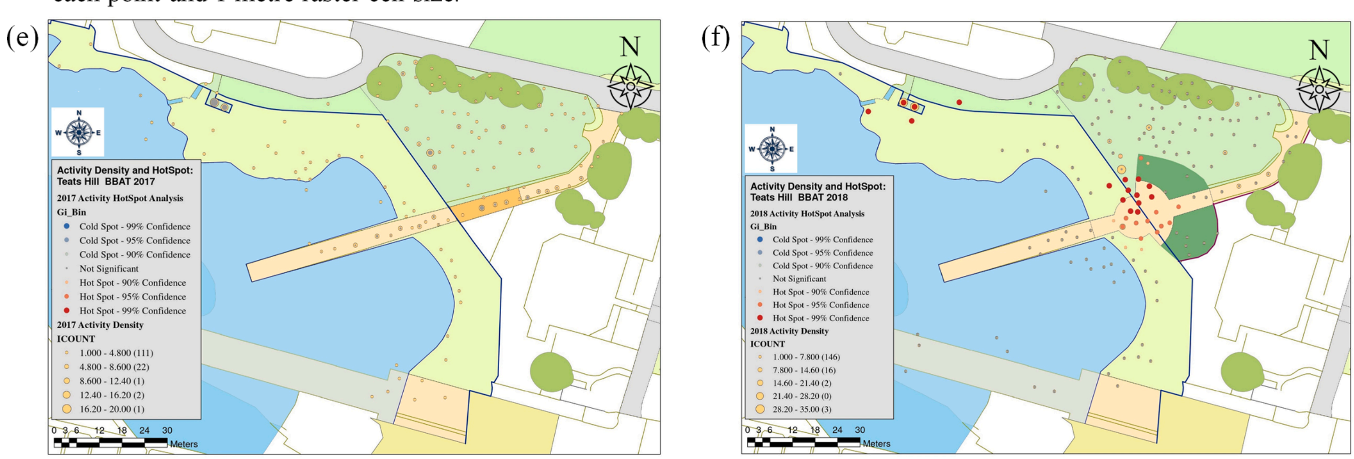
At T2 compared to T1 in the non-intervention area, visits increased by 81.12 % (Fig. 3a). Visits to the park increased by 101.48 %, whereas



Figures compare the distribution of different activity points at T1 and T2.



Figures compare the density of observed activity points using kernel density heat maps with a 4 metre radius around each point and 1 metre raster cell size.



Figures compare the hot spot analysis of activity points at T1 and T2 and statistically confirms the significance of the clustering of visitors at the lower slip road (the open-air theatre) in T2 despite overall low visit predictability.

Fig. 4. Spatial analysis (Fig. 4a-f) comparing visitor distribution and density of concentration depicting the main differences between T1 (2017) and T2 (2018).

visits to the upper slip road declined (-8.70 %). Moreover, at T2, weekday, afternoon, and evening visits increased by 117.31 %, 219.57 %, and 145.24 %, respectively.

Supporting H1a, the Kernel density pattern of visitors suggested a higher use of the site at T2 compared to T1. This is reflected in Fig. 4 (c&d), which means the open-air theatre is a clear new hotspot at T2 while the rest of the site is generally somewhat hotter than at T1, while the distribution – around the existing benches remaining in place – appears similar. While the heat maps tend to be relative and qualitative, the hot spot analysis shows more statistically significant patterns. This is

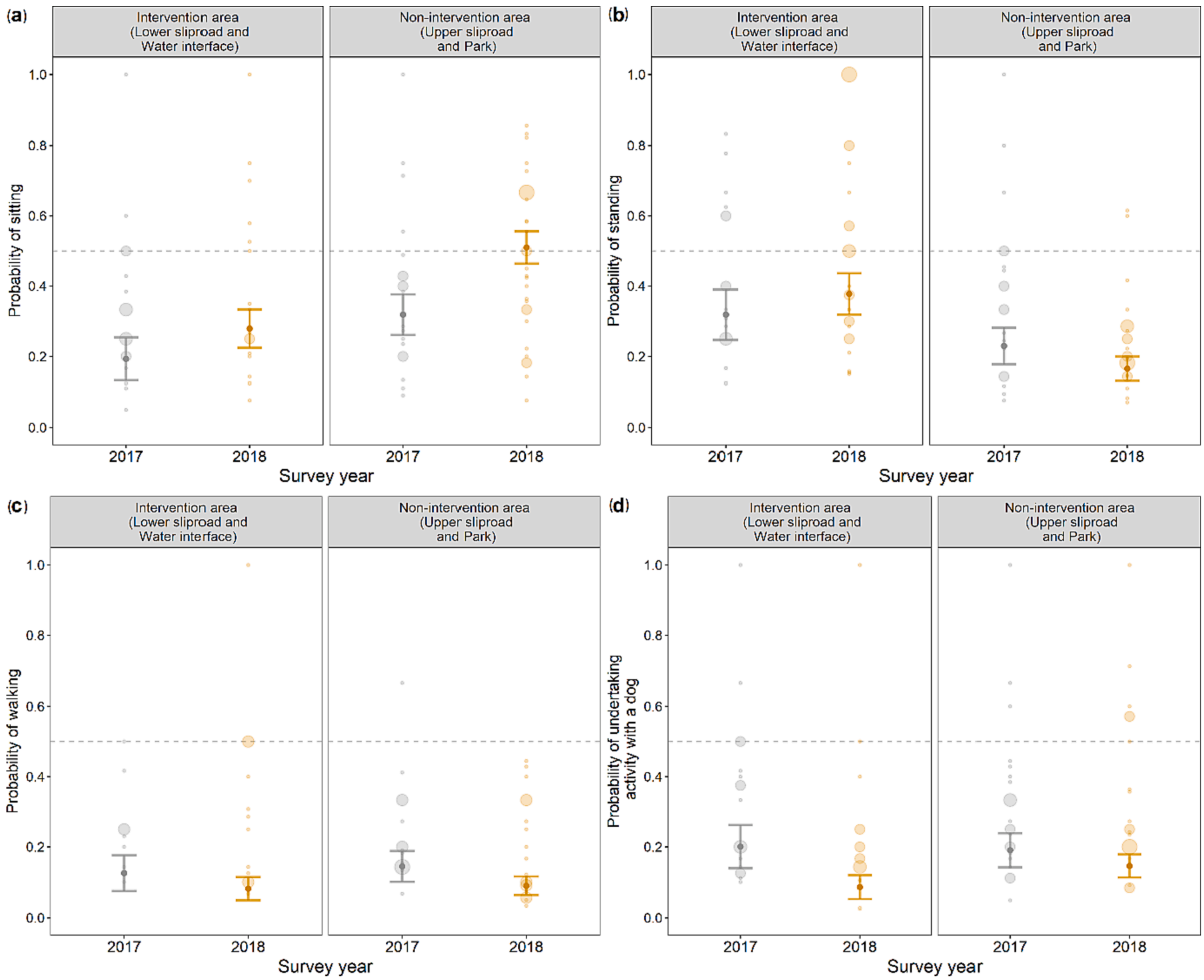


Fig. 5. Graphs comparing the probability of the occurrence of primary activities between the intervention area (lower slip road in T1/open-air theatre in T2 and water interface area) and non-intervention area (upper slip road and the park) across observation years for (a) sitting, (b) standing, (c) walking, and (d) activity with a dog.

reflected in Fig. 4(e&f), where the points along the access path have been removed to focus on the main intervention areas of the site. We can see that at T1 there were no especially significant hot spots, while at T2, there are a number at 99 % confidence clustered on or close to the open-air theatre and on the beach, as well as at another already existing viewpoint at the western end of the site. These findings support H1b that the intervention attracted more visitors at T2. Excluding the visitors on the access path, visits to the non-intervention area (the park) were more than in the intervention area, which supports H1c, and is reflected in Fig. 4d (more density blobs on the park) and Fig. 3a (increased number of visitors at the non-intervention area at T2) indicating a broader impact of the intervention beyond the open-air theatre itself.

3.2. The effect of the intervention on use of blue space and positive behaviours for health and well-being (H2)

3.2.1. Primary activities within the site (H2a)

At T2, standing increased in the site (including the access path), the intervention area, and the non-intervention area by 42.96 %, 90.38 % and 31.03 %, respectively (Table 1; Fig. 5b). The odds of standing were significantly higher in the intervention area at T2 (β = 2.50**; 95 % CI = 1.33, 4.73), further supporting H2a. Across both years and the site (excluding the access path), the odds of standing were higher for visitors who were not alone (in-pairs: β = 2.11***; 95 % CI = 1.43, 3.13; in a group: β = 3.01***; 95 % CI = 1.98, 4.59) and when it was raining (β = 4.46***; 95 % CI = 2.23, 8.91). The odds of standing were lower for women (β = 0.70*; 95 % CI = 0.51, 0.95) compared to men and for children (β = 0.42***; 95 % CI = 0.26, 0.67) and teenagers (β = 0.55*; 95 % CI = 0.34, 0.89) compared to adults (see Table 2). The spatial analysis also suggests that standing (Fig. 6b) had moved to the open-air theatre at T2.

The odds of walking or strolling within the site were higher for visitors who were in-pairs (β = 1.70*; 95 % CI = 1.05, 2.75) compared to those visiting alone, and increased along with outdoor temperature (β = 1.15*; 95 % CI = 1.01, 1.31). Between T1 and T2, activity with a dog declined across the site (-9.76 %) but increased in the non-intervention area (39.58 %). Spatial analysis showed that activities with a dog (Fig. 5d) were similarly distributed across both years, marginally

Table 2
Results from the H2 relating to site use and positive behaviours for health and well-being presented using binary logistic regressions. The first column records whether or not someone was observed in the intervention area as the response variable. The next three columns show whether or not someone was performing each respective activity as the response variable. The results here are presented as the Odds Ratio.

	Location	Primary activities				Secondary activities		
	Intervention area	Sitting	Standing	Walking	Activity with a Dog	Viewing	Use of phone	Socialising
(Intercept)	3.83	0.69	0.18	0.01 ***	0.82	0.08 **	0.04 *	0.30
	[0.65, 22.46]	[0.09, 5.37]	[0.03, 1.26]	[0.00, 0.16]	[0.10, 6.90]	[0.01, 0.45]	[0.00, 0.68]	[0.04, 2.38]
(a) Location								
Year (ref = 2017/T1)								
2018 (post-intervention/ T2)	0.86	1.60	0.89	0.52	0.87	2.63 ***	0.85	1.03
	[0.55, 1.33]	[0.92, 2.79]	[0.52, 1.55]	[0.26, 1.03]	[0.48, 1.59]	[1.62, 4.27]	[0.40, 1.85]	[0.59, 1.80]
Intervention area (ref = No)								
yes		0.58 *	1.53	0.88	1.00	1.18	0.83	1.00
		[0.35, 0.98]	[0.93, 2.52]	[0.47, 1.63]	[0.56, 1.77]	[0.72, 1.93]	[0.40, 1.73]	[0.63, 1.58]
Year (ref = 2017) × Intervention area (ref = No)								
2018 (open-air theatre and water interface area) × Yes		0.62	2.50 **	1.02	0.65	1.22	1.62	0.60
		[0.33, 1.16]	[1.33, 4.73]	[0.43, 2.39]	[0.29, 1.46]	[0.67, 2.22]	[0.61, 4.30]	[0.33, 1.07]
(b) Visitor characteristics (inclusivity)								
Gender (ref = Men)								
Women	0.77	1.08	0.70 *	1.06	2.45 ***	0.97	0.84	1.18
	[0.59, 1.00]	[0.82, 1.42]	[0.51, 0.95]	[0.70, 1.59]	[1.67, 3.59]	[0.74, 1.27]	[0.52, 1.36]	[0.90, 1.54]
Age group (ref = Adults)								
Children	1.37	0.40 ***	0.42 ***	0.80	0.40	0.48 **	0.08 *	1.71 **
	[0.93, 2.03]	[0.25, 0.64]	[0.26, 0.67]	[0.42, 1.51]	[0.16, 1.00]	[0.31, 0.74]	[0.01, 0.66]	[1.16, 2.51]
Teenagers	1.23	1.46	0.55 *	0.52	0.41 *	0.50 **	1.26	4.24 ***
	[0.84, 1.82]	[0.96, 2.20]	[0.34, 0.89]	[0.26, 1.05]	[0.19, 0.90]	[0.33, 0.77]	[0.66, 2.43]	[2.79, 6.44]
Older adults	0.59 *	0.93	1.16	0.80	1.02	2.83 ***	0.13 **	1.01
	[0.37, 0.95]	[0.59, 1.47]	[0.72, 1.88]	[0.40, 1.57]	[0.58, 1.78]	[1.81, 4.41]	[0.03, 0.59]	[0.65, 1.57]
Group structure (ref = Alone)								
In-pairs	1.09	0.91	2.11 ***	1.70 *	0.39 ***	1.35	0.24 ***	
	[0.78, 1.52]	[0.64, 1.30]	[1.43, 3.13]	[1.05, 2.75]	[0.25, 0.60]	[0.96, 1.88]	[0.12, 0.47]	
In a group	1.10	1.47 *	3.01 ***	0.86	0.09 ***	0.65 *	0.37 **	
	[0.77, 1.56]	[1.00, 2.15]	[1.98, 4.59]	[0.49, 1.52]	[0.04, 0.18]	[0.45, 0.94]	[0.20, 0.70]	
(c) Potential confounders								
Time of the week (ref = Weekday)								
Weekend	1.06	1.56	0.72	0.85	0.97	0.89	0.50	1.87 *
	[0.68, 1.66]	[0.93, 2.62]	[0.44, 1.16]	[0.45, 1.61]	[0.56, 1.70]	[0.58, 1.36]	[0.24, 1.06]	[1.10, 3.16]
Time of day (ref = Evening)								
Morning	0.44 *	0.62	1.85	1.05	1.50	1.97	1.59	0.40 *
	[0.20, 0.95]	[0.25, 1.54]	[0.81, 4.22]	[0.34, 3.20]	[0.60, 3.74]	[0.93, 4.16]	[0.50, 5.11]	[0.16, 1.00]
Lunchtime	0.62	1.46	1.04	1.22	0.63	1.86 *	0.91	0.65
	[0.35, 1.09]	[0.76, 2.81]	[0.56, 1.92]	[0.57, 2.63]	[0.30, 1.29]	[1.09, 3.17]	[0.39, 2.14]	[0.34, 1.27]
Afternoon	1.12	1.29	1.20	0.86	0.99	0.95	0.81	0.69
	[0.64, 1.98]	[0.66, 2.51]	[0.64, 2.24]	[0.39, 1.91]	[0.48, 2.06]	[0.54, 1.66]	[0.34, 1.94]	[0.36, 1.35]
Outdoor temperature	0.92	0.97	0.99	1.15 *	0.96	1.06	1.11	1.04
	[0.83, 1.01]	[0.87, 1.08]	[0.89, 1.09]	[1.01, 1.31]	[0.86, 1.07]	[0.97, 1.16]	[0.95, 1.28]	[0.93, 1.16]
Precipitation (ref = no rain)								
Some rain	1.20	0.21 **	4.46 ***	1.17	0.86	1.17	1.73	1.29
	[0.62, 2.32]	[0.08, 0.56]	[2.23, 8.91]	[0.45, 3.04]	[0.38, 1.98]	[0.60, 2.26]	[0.65, 4.57]	[0.60, 2.77]

(*continued on next page*)

Table 2 (*continued*)

	Location	Primary activities				Secondary activities		
	Intervention area	Sitting	Standing	Walking	Activity with a Dog	Viewing	Use of phone	Socialising
Model info								
Observations	1124	1124	1124	1124	1124	1124	1124	1124
Observation episodes	61	61	61	61	61	61	61	61
AIC	1457.21	1330.94	1164.24	767.01	803.87	1365.90	600.26	1382.61
BIC	1532.58	1416.36	1249.66	852.42	889.28	1451.32	685.67	1457.98
R2 (fixed)	0.05	0.15	0.16	0.08	0.36	0.17	0.32	0.11
R2 (total)	0.12	0.25	0.23	0.17	0.41	0.22	0.39	0.22

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.
Observations = The total number of observations across the two sampling years (2017 and 2018).
Observation episodes = The number of distinct two hour observation episodes which occurred during the 2017 and 2018 recording periods.

increasing in the park and the open-air theatre in T2 reflected in Fig. 6c. Across the site, the odds of participating in an activity with a dog was higher for women than men (β = 2,45***; 95 % CI = 1.67, 3.59), lower for teenagers compared to adults (β = 0.41*; 95 % CI = 0.19, 0.90) and also lower for people not visiting the site alone (in-pairs: β = 0.39***; 95 % CI = 0.25, 0.60; in a group: β = 0.09***, 95 % CI = 0.04, 0.18) (Table 2).

3.2.2. *Viewing blue spaces from the site (H2a):*

At T2, viewing increased in the site (including the access path), the intervention area, and the non-intervention area by 263.68 %, 188.10 % and 207.58 % respectively (Table 1). Quantitative results found the odds of viewing increased at T2 across the site (excluding the access path) (β = 2.63***; 95 % CI = 1.62, 4.27) with higher probability of occurrence in the intervention area (Fig. 7a). Moreover, across both years and the site, the odds of viewing were higher during lunchtime visits compared to evening (β = 1.86*; 95 % CI = 1.09, 3.17) and for older adults compared to adults (β = 2.83***; 95 % CI = 1.81, 4.41). The odds of viewing were reduced for visitors in a group (β = 0.65*; 95 % CI = 0.45, 0.94) compared to those who visit alone (Table 2). The spatial analysis (Fig. 8a) shows that viewing at T2 is more distributed across the entire site, with high concentrations at the open-air theatre and water interface area. Despite this, we did not quantitatively find an interaction between T2 and the intervention areas. Thus, H2a, which states that the intervention promoted positive behaviour for health and well-being, has been partially supported as the clearance of overgrown vegetation, which blocked views, appear to have drawn people to spend time looking at the view of the water and beyond, precisely in line with design intentions.

3.2.3. *Socialising, especially around the purpose-designed open-air theatre area (H2b)*

At T2, socialising increased in the site (including the access path), the intervention area, and the non-intervention area by 17.71 %, 81.54 %, and 106.48 % respectively (Table 1). The odds of socialising across both years and the site (excluding the access path) was higher for children (β = 1.71**; 95 % CI = 1.16, 2.51) and teenagers (β = 4.24***; 95 % CI = 2.79, 6.44) compared to adults, and during weekend visits (β = 1.87*; 95 % CI = 1.10, 3.16) but lower in the morning compared to the evening (β = 0.40*; 95 % CI = 0.16, 1.00) (Table 2). Spatial analysis showed that socialising (Fig. 8b) was associated with the access path at both T1 and T2, the open-air theatre, water interface at T2 in line with design intentions. However, this association was not found in the quantitative analysis. Spatial analysis shows that at T2 the open-air theatre attracted more visitors in pairs and in a group (Fig. 9 b&c). Thus, H2b has been partially supported by the intervention.

3.2.4. *Sitting and relaxing, reflecting comfort and feelings of safety (H2c)*

Sitting increased at T2 in the site (including the access path), the intervention area and the non-intervention area by 172.57 %, 131.25 %, and 187.50 %, respectively (Table 1; Fig. 5a). Across both years, the odds of sitting were lower in the intervention area compared to the rest of the site (β = 0.58*; 95 % CI = 0.35, 0.98). Across both years and the site (excluding the access path), the odds of sitting were lower for children compared to adults (β = 0.40***; 95 % CI = 0.25, 0.64), higher for visitors in a group compared to those who visit alone (β = 1.47*; 95 % CI = 1.00, 2.15) and lower when it was raining (β = 0.21**; 95 % CI = 0.08, 0.56) (Table 2). Refreshment activities significantly increased in the intervention area by 750.00 %. Overall, phone use declined in the site between T1 and T2 (−10.94 %), but an increase was observed within the intervention and non-intervention areas (23.53 % and 37.50 % respectively) (Table 1; Fig. 7b). The odds of using a phone were lower for children (β = 0.08*; 95 % CI = 0.01, 0.66) and teenagers (β = 0.13**; 95 % CI = 0.03, 0.59) compared to adults, and also lower for visitors who were not alone (in pairs: β = 0.24***; 95 % CI = 0.12, 0.47; in a group: β = 0.37**; 95 % CI = 0.20, 0.70). Spatial analysis showed that sitting was

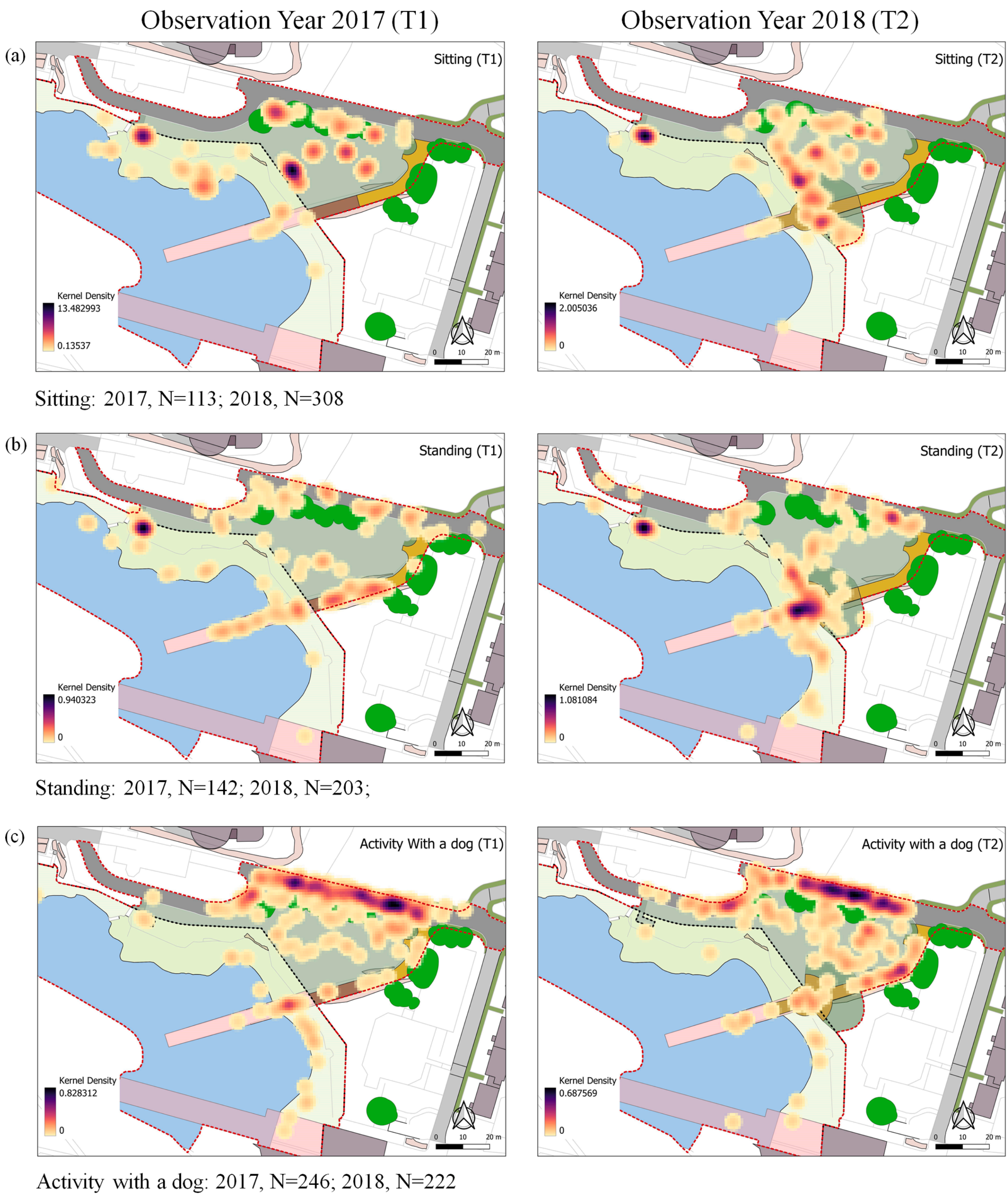


Fig. 6. Heat maps illustrating the density and distribution of health promoting primary activities across different behaviour settings within the site.

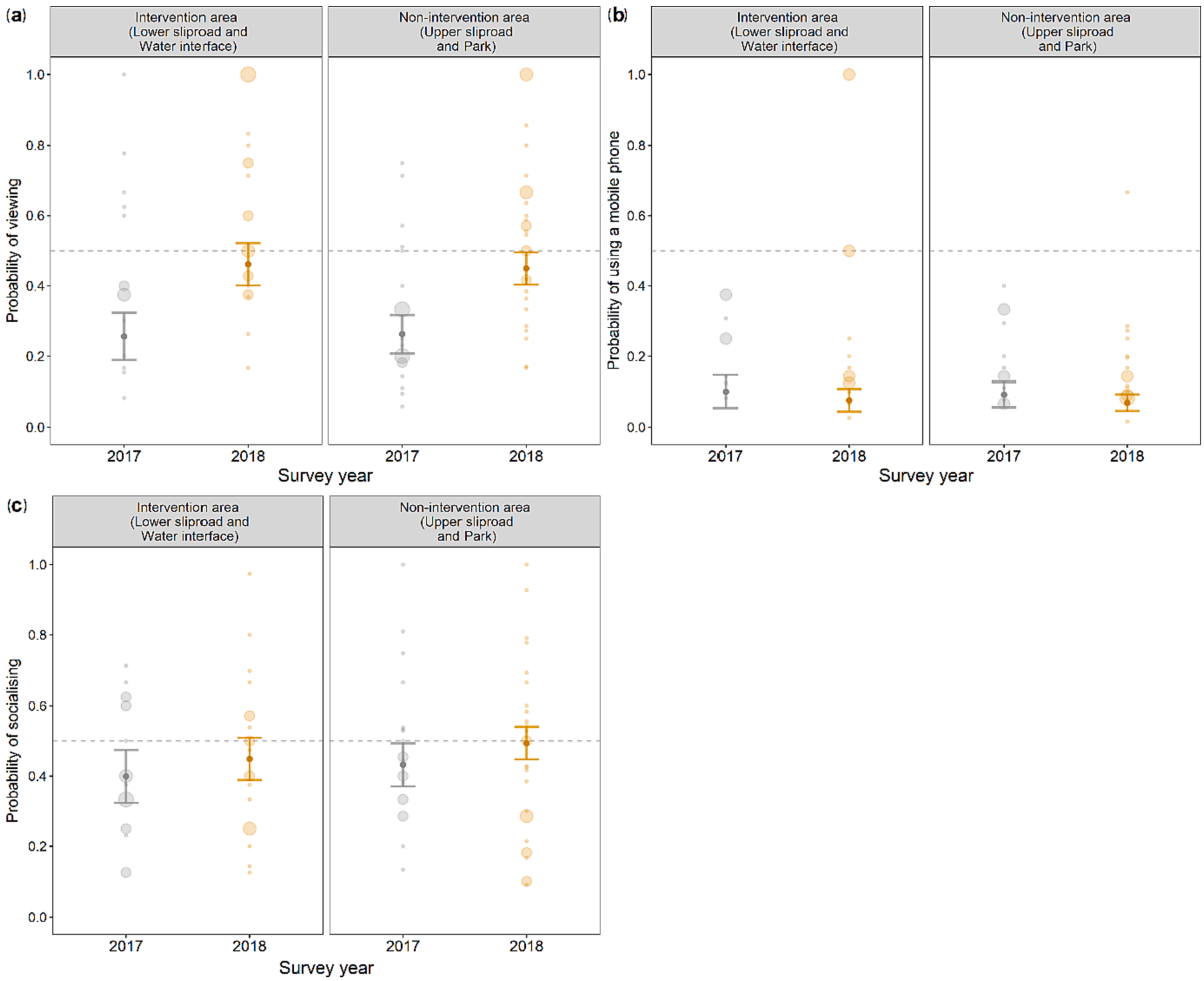


Fig. 7. Graphs comparing the probability of the occurrence of secondary activities between the intervention area (lower slip road in T1/ open-air theatre in T2 and water interface area) and non-intervention area (upper slip road and the park) across observation years for (a) viewing, (b) using a mobile phone, and (c) socialising.

associated with the park across both years and moved closer to the beach - well-distributed along the cliff edge - and in the open-air theatre in line with the design intention (Fig. 6a). The use of mobile phone declined at T2 across both the intervention and non-intervention area (Fig. 7b) however, moved closer to the open-air theatre and cliff-edge (Fig. 8c). Thus, H2c has been partly supported by the intervention.

3.3. Effect of the intervention on gender and greater inclusivity and diversity of site visitors (H3).

3.3.1. Women (H3a)

At T2 compared to T1, the number of women visiting increased in the site (including the access path), the intervention area, and the non-intervention area by 23.34 %, 193.02 %, and 92.73 %, respectively (Table 1; Fig. 10a). Quantitative analysis showed that the odds of women being in the intervention area was higher at T2 ($\beta = 2.16^{**}$; 95 % CI = 1.24, 3.74) compared to men, despite the odds of women being in the intervention area across both years being lower ($\beta = 0.46^{**}$; 95 % CI = 0.30, 0.73). Supporting H3a, spatial analysis (Fig. 11b) shows higher density clusters for women in the park, open-air theatre, cliff edge, and the beach at T2 compared to T1 despite fewer women being observed in the site compared to men. The odds of a child being a girl were lower ($\beta = 0.52^{**}$; 95 % CI = 0.35, 0.77), and women had higher odds of being in a group ($\beta = 2.09^{***}$; 95 % CI = 1.50, 2.91). These results support H3a that the intervention has improved the gender equality of site users.

3.3.2. Children and teenagers (H3b)

At T2 compared to T1, children increased in the site (including the access path), the intervention and the non-intervention areas by 26.63 %, 57.89 % and 54.29 % respectively. Whilst teenagers increased by 19.71 %, 235.00 % and 158.06 % respectively (Table 1; 10b). Supporting H3b, this is reflected in Fig. 12 a&b, which shows higher density clusters for children and teenagers in the park, open-air theatre, and the beach at T2 compared to T1. Across both years and the site (excluding the access path), children and teenagers had higher odds of visiting the site with someone (Table 3), and children had higher odds of being at the site in the afternoon ($\beta = 2.70^{*}$; 95 % CI = 1.03, 7.12).

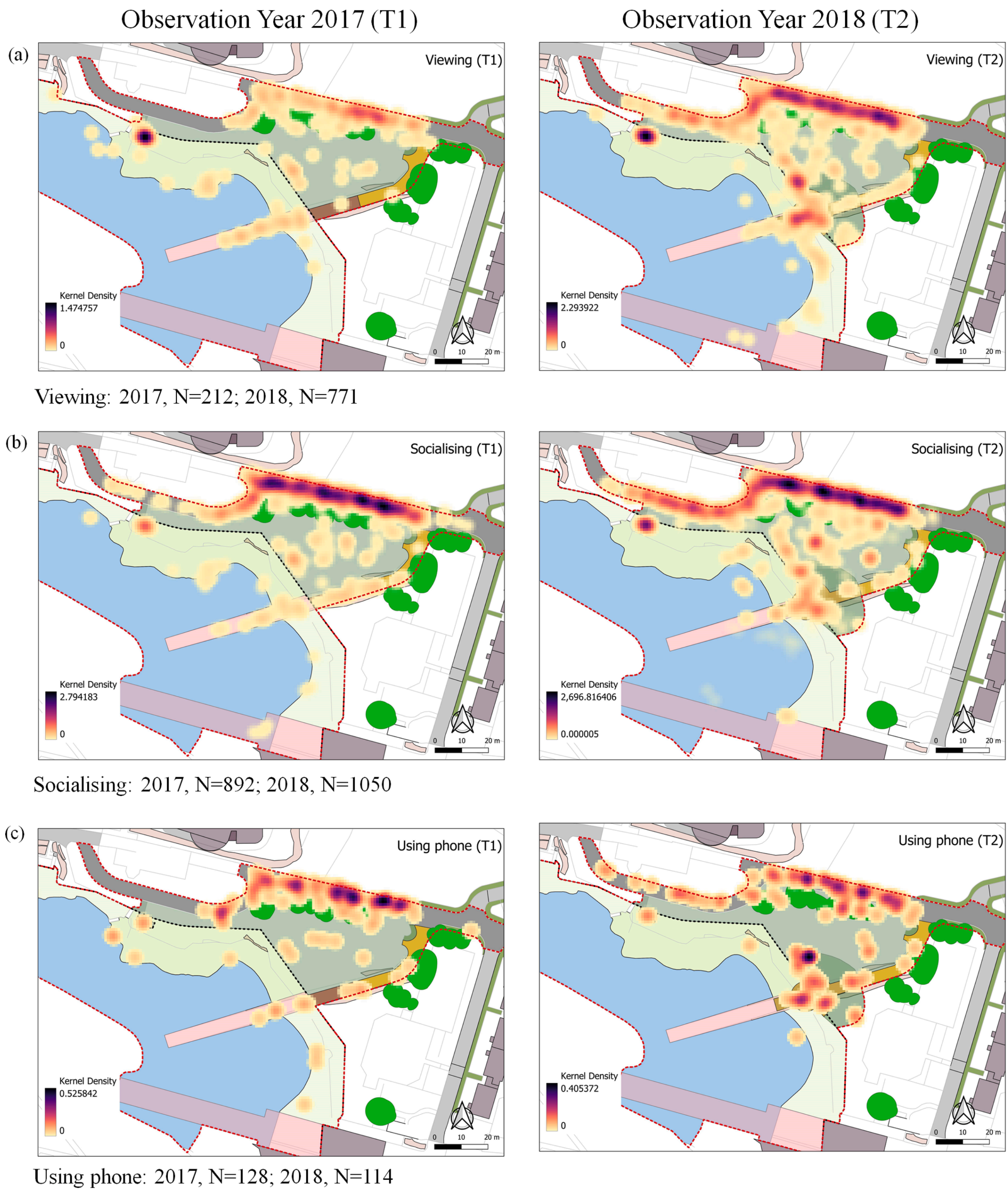


Fig. 8. Heat maps illustrating the density and distribution of health-promoting secondary activities across different behaviour settings within the site.

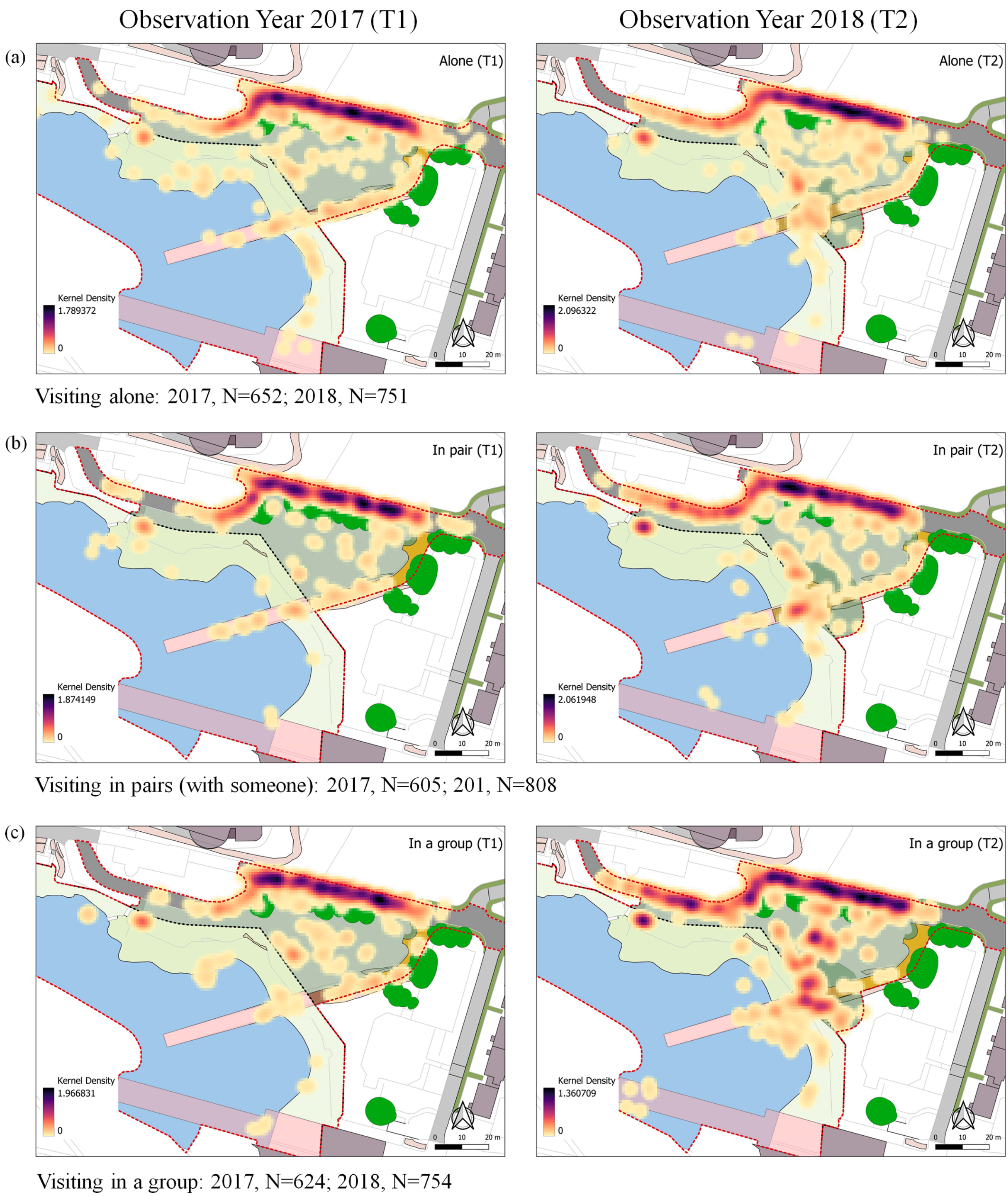
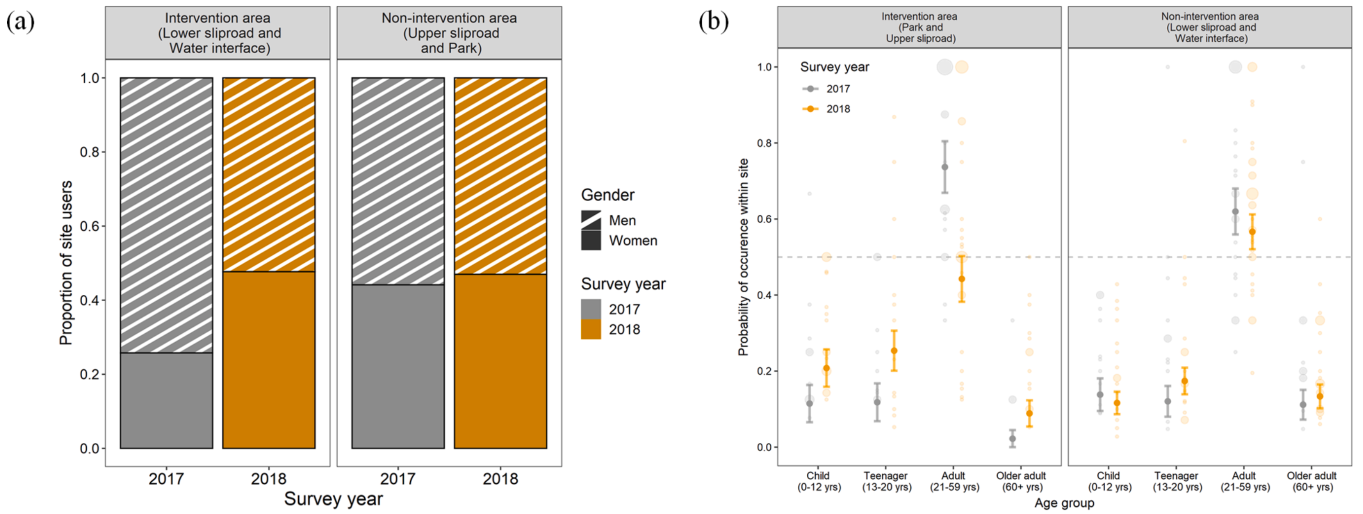


Fig. 9. Heat maps illustrating the density and distribution of visitors by group structure across different behaviour settings within site.



The proportion of activities for gender.

Probability of the distribution of the activities for the age group.

Fig. 10. Graphs comparing site use across observation years for the intervention area (lower slip road in T1/open-air theatre in T2 and water interface area) and non-intervention area (upper slip road and the park) by gender and age group.

3.3.3. *Older adults (H3c)*

At T2 compared to T1, older adults increased in the site (including the access path), the intervention area, and the non-intervention area by 34.42 %, 500.00 %, and 113.79 %, respectively. Despite this percentage increase in the intervention area, quantitative analysis shows that across both years, older adults had lower odds of being in the intervention area compared to all other age groups ($\beta = 0.21^{**}$; 95 % CI = 0.07, 0.65), and lower odds of being in a group ($\beta = 0.52^{*}$, 95 % CI = 0.31, 0.89) compared to visiting alone. Spatial analysis shows at T2 older adults moved closer to the water, and more visited the open-air theatre (Fig. 12 d). Our results show that we are only some of the way to achieving H3c; that the intervention increased blue space accessibility for older adults.

4. Discussion

This research complements the knowledge of blue spaces' health and well-being potential by using behaviour observation and mapping and a theory-based approach to designing and implementing a small-scale blue space intervention intended to enhance the place affordance and promote healthy behaviour, relaxation, and socialisation.

Our first hypothesis (H1) that the blue space intervention would increase visitors and draw people closer to the sea was fully supported. The higher number of visitors and density in the intervention area (open-air-theatre) and the non-intervention area (the park) at T2 were evident both spatially and statistically. A shift and higher concentration of visitors towards the water's edge at the open-air theatre and the water interface area at T2 shows the design improved blue space accessibility (Beck, 2009) and popularity among locals and visitors by improving place attractiveness, place quality, connectivity to the sea (physically and visually), place affordance for healthy behaviour (Koohsari et al., 2015), and by removing physical and visual permeability barriers to the sea (Varna & Tiesdell, 2010; Carmona, 2019).

Our second hypothesis (H2) that at Teats Hill, the design intervention would trigger an increased use of blue space and positive behaviours for health and well-being with a range of healthy behaviour, socialisation, and sitting and relaxing activities was partly supported. Viewing, standing and socialising significantly increased in line with the intervention type and the design intention and more visitors were drawn to the open-air theatre, water interface area and the park generally because of the focused redevelopment. Moreover, the heat maps confirmed that the open-air theatre promoted socialising.

At T2, an increased density of activities in and around the open-air theatre, demonstrated the positive impact of the intervention on healthy behaviour. In line with the aim of this design, spaces for sitting and gathering are vital spatial components of any public space (Putriutami et al., 2020), which trigger resultant activities (e.g. socialising, viewing, eating and drinking) and these activities intensify with good accessibility, great views, and comfortable conditions for relaxation, and may encourage visitors to linger (Gehl, 2011). Interventions such as cutting back overgrown vegetation along the cliff edge, orienting people towards the open-air theatre, facilitating sitting, restoring open views and views of the water, and improving place aesthetics, enhanced user experiences. Besides the amplified use of the open-air theatre (the intervention) at T2, passive recreation doubled in the park as a whole (the non-intervention area), indicating a positive impact due to the overall facelift. Beyond the possibilities for vigorous activities (e.g. exercise, swimming), findings such as that moderate (e.g. strolling) and passive activities (e.g. sitting, viewing) in blue spaces support psychological health and social cohesion (Brown, 2020; Georgiou et al., 2021; Garrett et al., 2019), align with the results obtained in this present study. Further, our results are consistent with earlier research that exposure to blue space through viewing water promotes salutogenic effects (Dempsey et al., 2018).

Our third hypothesis (H3) that the intervention would increase social inclusivity and a diversity of visitors was partly supported. This is consistent with earlier evidence that well-designed and accessible, functional, and attractive natural environments offer local recreational destinations, promote positive social ties, and spontaneous activities and interactions (Mazumdar et al., 2018; Paydar & Fard, 2021), and are especially beneficial for older adults (Benton et al., 2021). In Teats Hill, improved accessibility to water and place quality, removal of physical barriers and increased functionality and safety and the open-air theatre at T2 led to increased visits by women, children, teenagers, older adults, pairs, and groups, suggesting increased inclusivity and diversity and demonstrating the positive impact of the intervention. Our results reinforce other findings suggesting that blue spaces promote social

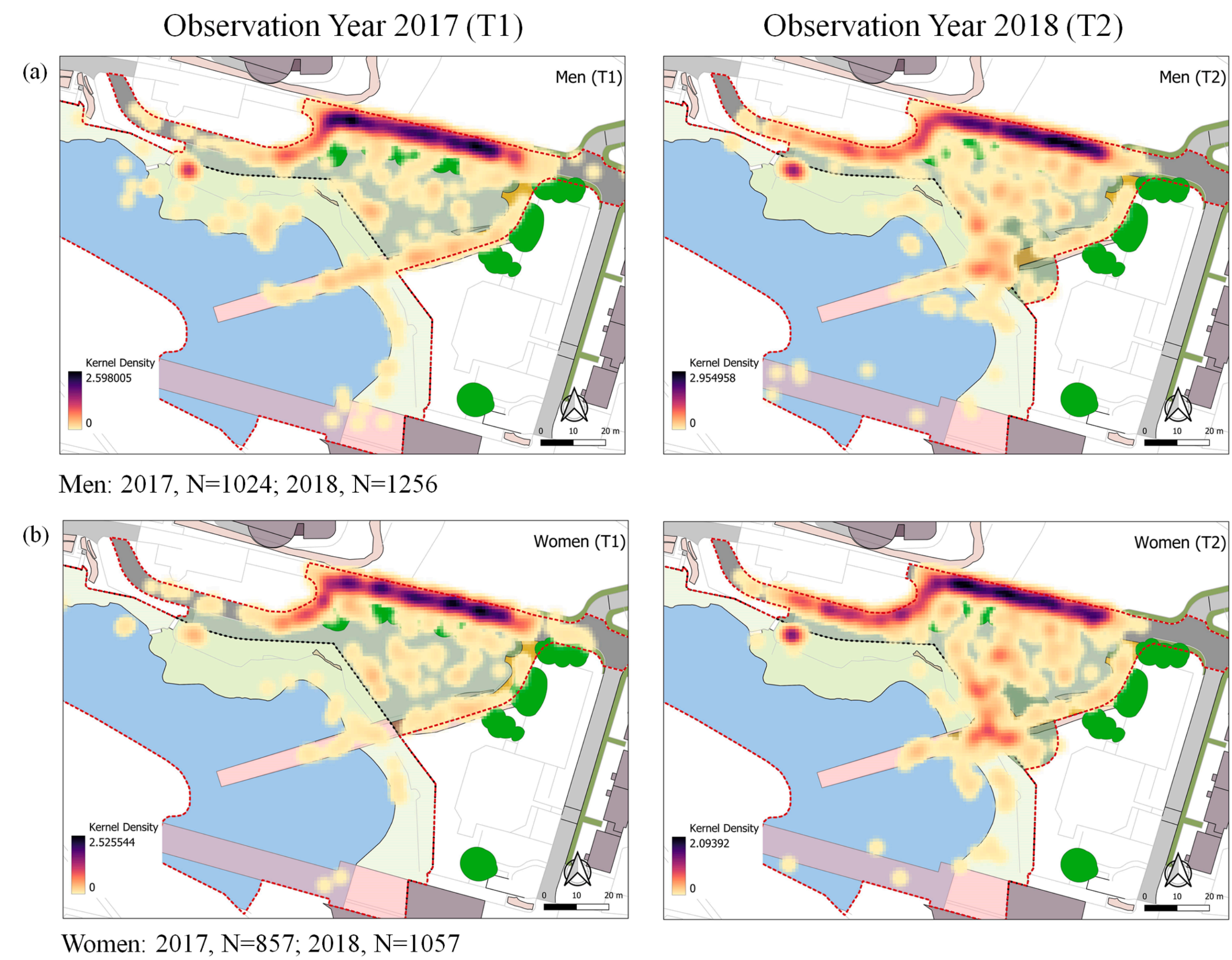


Fig. 11. Heat maps illustrating the density and distribution of visitors by gender.

cohesion (Ashbullby et al., 2013). The intervention created a relaxing environment, which was expected to have provided psychological benefits to older adults, underpinning the existing knowledge that viewing blue spaces is physiologically and psychologically beneficial (Garrett et al., 2019; Bell et al., 2015). These results also reinforce other findings suggesting positive well-being was related to the perceived post-intervention site quality and safety at Teats Hill (van den Bogerd et al., 2021). In addition, this study reinforces the concept that small neighbourhood natural spaces are essential for socialising and resting, and benefit from improved place quality, through serenity, attractiveness, and the place context (Peschardt and Stigsdotter, 2013).

5. Strengths and limitations

One of this study's major strengths is that, as far as we know, it is the first to investigate the effects of a blue space intervention using a GIS-based behaviour observation and mapping method (BBAT). It highlights the benefits of theory- and evidence-based design, intending to increase blue space access and improve affordances for relaxing activities, social inclusivity, and psychological well-being. Nevertheless, we recognise several limitations in the study. Firstly, the study did not compare Teats Hill with other sites elsewhere. Instead, we compared the same site's pre-and post-intervention and non-intervention areas. The method was adopted because two urban blue spaces are not comparable behaviour settings and present varied physical, social and aesthetic domains, making standard experimental control virtually impossible (Mishra et al., 2021). Second, behaviour observation mapping is time and resource-consuming, so we concentrated our observations only during the warmer periods for both years to collect the most diverse and rich behaviour data. Extension of observations to the rest of the year would provide more comprehensive data. Thirdly, we limited our study to the before-and-after intervention period rather than extending observations into later post-intervention years. A third wave of behaviour observation could be applied to test the effect of the intervention over a more extended period of time.

6. Conclusions

By co-creating a small-scale physical intervention at the Teats Hill in Plymouth, UK, the present study tested its impact on blue space accessibility, place affordance, functionality and social and psychological benefits, considered critical for the local community's well-being. We performed a pre-post comparison of visitor behaviour at both the intervention and non-intervention areas of the site. We examined the impact of the intervention on primary activities, viewing, socialising, sitting, and relaxing activities, and visitors' inclusivity and diversity. Post-intervention, both quantitative and spatial analysis confirmed that the intervention attracted more visitors, brought more people close to the water, increased healthy forms of behaviour and socialising, and improved visitor diversity and inclusivity. We conclude that the theory-

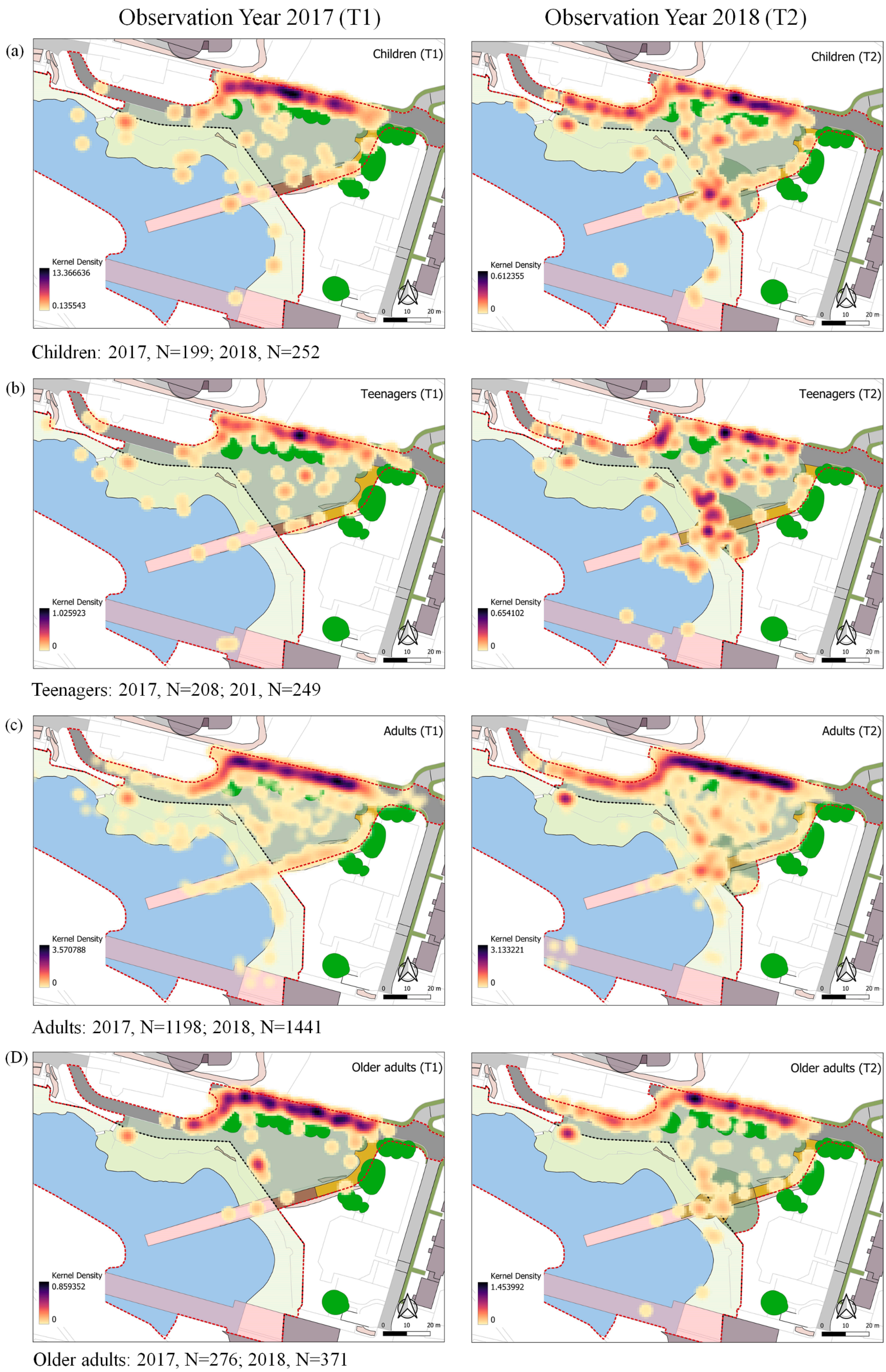


Fig. 12. Heat maps illustrating the density and distribution of users by age groups across different behaviour settings (Table 1-b) within the site.

Table 3
Results of the H3 models which looked at inclusivity. These are also binary logistic regressions, presented as Odds Ratios. The response variable of the first model compares males (0) to females (1) in terms of their site use. The subsequent models compare each respective age group to all other age groups e.g., 'Children' compares children (1) to teenagers, adults, and older adults (0).

	Gender	Age group				Group structure		
	Women	Children	Teenagers	Adult	Older adult	Alone	With someone	In a group
(Intercept)	1.54	0.24	0.03	3.13	0.03 *	0.71	0.83	0.02
	[0.39, 5.99]	[0.01, 5.59]	[0.00, 1.30]	[0.55, 17.83]	[0.00, 0.47]	[0.12, 4.30]	[0.09, 7.90]	[0.00, 1.88]
(a) Location								
Year (ref = 2017)								
2018 (post-intervention)	1.19	0.93	1.12	0.87	1.25	0.97	1.60	0.61
	[0.82, 1.72]	[0.42, 2.07]	[0.43, 2.90]	[0.54, 1.39]	[0.58, 2.69]	[0.59, 1.62]	[0.85, 3.00]	[0.20, 1.86]
Intervention area (ref = No)								
yes	0.46 ***	0.81	1.23	1.61	0.21 **	1.22	1.20	0.64
	[0.30, 0.73]	[0.41, 1.61]	[0.61, 2.47]	[1.00, 2.60]	[0.07, 0.65]	[0.76, 1.94]	[0.73, 1.96]	[0.37, 1.12]
Year (ref = 2017) × Intervention area (ref = No)								
2018 (open-air theatre) × Yes	2.16 **	2.30	0.87	0.45 **	3.49	0.61	0.82	2.16 *
	[1.24, 3.74]	[0.99, 5.32]	[0.37, 2.05]	[0.25, 0.82]	[1.00, 12.20]	[0.33, 1.12]	[0.45, 1.52]	[1.08, 4.30]
(b) Visitor characteristics (inclusivity)								
Gender (ref = Men)								
Women		0.48 ***	1.02	1.23	1.35	0.63 **	0.94	1.67 **
		[0.32, 0.71]	[0.69, 1.51]	[0.94, 1.61]	[0.89, 2.03]	[0.47, 0.84]	[0.71, 1.25]	[1.21, 2.30]
Age group (ref = Adults)								
Children	0.52 **					0.08 ***	1.15	5.48 ***
	[0.35, 0.77]					[0.04, 0.16]	[0.77, 1.73]	[3.50, 8.57]
Teenagers	0.88					0.21 ***	0.97	4.67 ***
	[0.61, 1.27]					[0.13, 0.34]	[0.64, 1.47]	[2.93, 7.45]
Older adults	1.16					1.11	0.76	1.25
	[0.77, 1.74]					[0.73, 1.71]	[0.47, 1.22]	[0.73, 2.15]
Group structure (ref = Alone)								
In-pairs	1.32	7.14 ***	2.59 **	0.47 ***	0.61			
	[0.96, 1.82]	[3.42, 14.94]	[1.47, 4.56]	[0.34, 0.66]	[0.37, 1.02]			
In a group	2.09 ***	15.20 ***	5.51 ***	0.20 ***	0.52 *			
	[1.50, 2.91]	[7.31, 31.57]	[3.12, 9.74]	[0.14, 0.28]	[0.31, 0.89]			
(c) Potential confounders								
Time of the week (ref = Weekday)								
Weekend	1.01	1.67	0.86	0.99	1.04	0.73	0.89	2.58
	[0.73, 1.39]	[0.80, 3.47]	[0.34, 2.16]	[0.65, 1.52]	[0.52, 2.09]	[0.45, 1.16]	[0.50, 1.61]	[0.84, 7.90]
Time of day (ref = Evening)								
Morning	0.90	0.45	0.30	1.50	1.90	3.23 **	0.58	0.29
	[0.50, 1.63]	[0.10, 1.98]	[0.06, 1.47]	[0.69, 3.24]	[0.53, 6.81]	[1.45, 7.20]	[0.21, 1.60]	[0.04, 2.10]
Lunchtime	1.19	1.22	0.48	0.91	1.39	1.46	1.22	0.58
	[0.79, 1.78]	[0.46, 3.26]	[0.16, 1.44]	[0.53, 1.56]	[0.55, 3.53]	[0.81, 2.65]	[0.58, 2.54]	[0.14, 2.37]
Afternoon	1.25	2.70 *	0.58	0.81	1.11	1.72	1.29	0.50
	[0.81, 1.91]	[1.03, 7.12]	[0.20, 1.70]	[0.47, 1.39]	[0.43, 2.87]	[0.94, 3.16]	[0.61, 2.70]	[0.12, 2.03]
Outdoor temperature	0.94	0.86	1.05	1.00	1.07	1.01	0.95	1.11
	[0.88, 1.01]	[0.72, 1.01]	[0.87, 1.27]	[0.92, 1.10]	[0.93, 1.24]	[0.92, 1.11]	[0.84, 1.07]	[0.88, 1.40]
Precipitation (ref = no rain)								
Some rain	0.92	0.86	0.58	1.33	1.43	0.96	0.81	2.37
	[0.53, 1.59]	[0.28, 2.63]	[0.15, 2.27]	[0.67, 2.63]	[0.47, 4.39]	[0.48, 1.89]	[0.34, 1.90]	[0.62, 9.11]

(*continued on next page*)

Table 3 (*continued*)

	Gender	Age group				Group structure		
	Women	Children	Teenagers	Adult	Older adult	Alone	With someone	In a group
Model info								
N	1124	1124	1124	1124	1124	1124	1124	1124
N (episode_new)	61	61	61	61	61	61	61	61
AIC	1513.74	799.88	838.53	1389.94	733.73	1233.25	1318.08	1138.35
BIC	1594.14	870.23	908.88	1460.28	804.08	1308.62	1393.45	1213.72
R2 (fixed)	0.06	0.31	0.16	0.16	0.12	0.27	0.03	0.16
R2 (total)	0.08	0.44	0.41	0.21	0.25	0.32	0.18	0.54

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

based blue space intervention achieved the desired results. Therefore, we suggest that planners, landscape architects, urban designers, and social and public health researchers who focus on the social effectiveness of blue space-based behaviours for health and well-being should advance the evidence-based co-creation of blue spaces in order to implement more effective urban blue space planning and design solutions. This case study intervention provides a long-term social and recreational infrastructure at Teats Hill, which promotes the health and well-being of the local population and improves place attachment and identity values among local residents.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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