Landscape and Urban Planning 178 (2018) 18–31

Contents lists available at ScienceDirect

Landscape and Urban Planning

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

Research Paper

An evaluation of participatory mapping methods to assess urban park benefits

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ARTICLE INFO

Keywords:
Urban parks
Physical activity
Benefits
Public participation GIS
PPGIS
Urban planning

ABSTRACT

Traditional urban park research has used self-reported surveys and activity logs to examine relationships between health benefits, park use, and park features. An alternative approach uses participating mapping methods. This study sought to validate and expand on previous participatory mapping research methods and findings and address spatial scaling by applying these methods to a large urban park system. Key challenges for spatial scaling included ambiguity in park classification and achieving representative sampling for larger and spatially-dispersed urban residents. We designed an internet-based public participation GIS (PPGIS) survey and used household and volunteer sampling to identify the type and locations of urban park benefits. Study participants (n = 816) identified locations of physical activities and other urban park benefits (psychological, social, and environmental) which were analyzed by park type. Consistent with previous suburb-scale research, we found significant associations between urban park type and different urban park benefits. Linear parks were significantly associated with higher intensity physical activities; natural parks were associated with environmental benefits; and community parks were associated with benefits from social interaction. Neighborhood parks emerged as significantly associated with psychological benefits. The diversity of park activities and benefits were positively correlated with park size. Distance analysis confirmed that physical benefits of parks were closest to participant domicile, while social and environmental benefits were more distant. These results validate previous suburb-scale findings despite greater variability in park types and sample populations. Future urban park research using participatory mapping would benefit from greater effort to obtain participation from under-represented populations that can induce nonresponse bias, and analyses to determine whether system-wide results can be disaggregated by suburb or neighborhood to address social inequities in urban park benefits.

1. Introduction

Urbanization is a dominant global trend with over half the world's population now living in cities (United Nations, 2015). Urban parks and greenspaces are widely held to contribute to human well-being and quality of life (Chiesura, 2004; Larson et al., 2016), but the empirical evidence for the link between human well-being and urban green space is weak due to poor study design, confounding effects, bias or reverse causality, and weak statistical associations (Lee & Maheswaran, 2011). The diversity and variability in urban populations, in combination with the heterogeneity of urban physical environments, make assessing urban greenspace benefits challenging. Urban design and planning outcomes that provide for parks and conserve greenspaces appear broadly justified based on *perceived* benefits, but parks and greenspaces do not contribute equally to the collective benefit enjoyed by urban inhabitants. In many cases, physical, psychological, and social health benefits appear inequitably distributed across urban populations (Jennings, Larson, & Yun, 2016). Further, perceived access to urban parks (Wang, Brown, Liu, & Mateo-Babiano, 2015) or a favorable orientation to nature (Lin, Fuller, Bush, Gaston, & Shanahan, 2014) appear more important than geographic access or proximity in predicting urban park use.

A variety of social research methods have been used to examine the putative benefits of urban parks and greenspaces. Participatory mapping methods, alternatively called public participation GIS (PPGIS), participatory GIS (PGIS), or volunteered geographic information systems (VGI), are increasingly used as a social research tool to assess the multiple benefits of urban parks and greenspaces. These methods offer

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https://doi.org/10.1016/j.landurbplan.2018.05.018
Received 20 June 2017; Received in revised form 19 May 2018; Accepted 21 May 2018
0169-2046/

an alternative to self-reporting surveys, activity logs, and direct observation methods such as SOPARC (McKenzie, 2005) for identifying the public health benefits from park activities (Brown, Schebella, & Weber, 2014). Further, these participatory mapping methods have the flexibility to identify broader social values and cultural ecosystem services associated with urban greenspaces (Tyrväinen, Mäkinen, & Schipperijn, 2007; Ives et al., 2017; Rall, Bieling, Zytynska, & Haase, 2017; Ribeiro & Ribeiro, 2016).

Participatory mapping methods for assessing urban park and greenspace benefits have multiple threats to research validity. Some of the key validity issues for the spatial mapping of benefits include the variables/constructs being mapped, spatial scale of the study area (e.g., park, suburb, or entire urban area), physical landscape variability (e.g., water, vegetation, topography), park/greenspace facilities/amenities, distance from domicile, accessibility, park/greenspace classification, and population sampling representativeness. To date, these methodological issues have not been comprehensively addressed within the same study, with reported studies examining a subset of these research issues.

In this study, the research objectives are to: (1) assess whether findings about the distribution of park benefits (physical, environmental, psychological, social) identified in previous participatory mapping studies that were limited in scope and scale are applicable to a large, diverse urban park system; and (2) examine the methodological challenges for scaling-up participatory mapping methods to assess urban park benefits in a large urban park system.

1.1. Review of related participatory mapping research

Brown et al. (2014) examined the distribution of urban park benefits (physical, psychological, social, and environmental) by park type using a park classification system developed by the National Recreation and Parks Association (NRPA) (Mertes & Hall, 1996). The study relied on a predominantly volunteer sample of urban residents (n = 242 participants) living in one suburb in the larger urban area of Adelaide, Australia. The study found that different urban park types provide opportunities for physical activities with differential health benefits. Linear parks provided the greatest overall physical benefit while other park types provided important psychological, social, and environmental benefits. Distance to park was not a significant predictor of physical activity but park size was related to benefits with larger parks providing greater and more diverse benefits. The potentially confounding variables of park accessibility, park amenities, and physical landscape characteristics were not examined.

Ives et al. (2017) implemented a PPGIS study in four urbanising suburbs in the Lower Hunter region of NSW, Australia, and requested residents (n = 418 participants) to identify important values of greenspace. The analyses examined the relationship between mapped values to physical landscape characteristics and also evaluated a simple greenspace classification typology (general, natural, sportsfield). The most frequently mapped value was physical activity and the majority of mapped values reflected positive attributes of greenspaces. Significant predictors for multiple greenspace values were distance to water and suburb identity, while the greenspace category was not significantly related to mapped values.

Rall et al. (2017) examined patterns of perceived cultural ecosystem services (CES) in the city of Berlin mapped by residents using convenience sampling (n = 562 participants). The study examined the distribution of CES by land cover classification. About three-quarters of all CES were mapped in urban greenspaces or forests. The study found spatial differentiation of perceived cultural ecosystem services (CES) in greenspaces where the density of CES decreased from the inner to the outer edges of the city. Recreation, social, cultural heritage, and identity services were concentrated more heavily in the inner-city, while biodiversity, spiritual, inspirational, nature experience and educational services were more spatially scattered.

Bijker and Sijtsma (2017) examined whether greenspaces at different distances are important for the wellbeing of urban dwellers. The study focused on urban residents drawn from internet panels in three countries (Germany, Denmark, Netherlands: n = 3763 respondents). Participants were asked to identify natural places that were attractive, valuable, or important at four different spatial scales: local, regional, national, or world. The attractiveness of natural places increased with spatial scale while local natural places were visited most frequently. As the spatial scale expanded from the local area, more greenspace qualities were identified. At all spatial scales, "green nature", recreation, and water qualities were the most frequently identified. Urban residents appear to have a "portfolio" of favorite places at multiple scales with local places being less special, but visited more frequently to counterbalance the stressful effects of population density. Places at the local and regional level especially provided opportunities for physical and social activities.

Pietrzyk-Kaszyńska, Czepkiewicz, and Kronenberg (2017) used participatory mapping to assess the non-monetary values of greenspaces in three cities in Poland. The study relied on sampling of volunteer participants (n = 1640) who identified important urban greenspaces on a map, both formal and informal greenspaces, and who provided qualitative statements for their importance. The study found between 17% and 41% of places where respondents spent time were areas outside of formal greenspaces that were valued for their greenness, pleasant views, uniqueness, wild character and natural habitats. The findings highlighted the need to identify and include informal greenspaces in urban spatial planning and governance.

With the exception of the Brown et al. (2014), these studies assessed park benefits indirectly through measurement of landscape values, ecosystem services, or park qualities, and none of the studies implemented both household and voluntary/convenience samples in the recruitment of study participants. The novelty of this research is the direct measurement of urban park benefits in a large urban park system using participatory mapping methods, the inclusion of multiple sampling methods to evaluate potential bias and representativeness, and the identification of park classification issues when applying the methods to a large urban park system.

1.2. Study purpose and research questions

This study seeks to advance knowledge about the strengths and limitations of participatory mapping as a social research method for identifying urban park benefits in a large urban park system. We follow the initial design of Brown et al. (2014) who identified urban park activities and benefits (physical, psychological, social, and environmental) by park type in a study of a suburb in Adelaide. However, this study is more than a replication study and contains new research design innovations in addition to addressing the important issue of methodological scaling by applying the participatory mapping process to a large urban area and park system located in Brisbane, Australia (est. pop. 1.2 million). The key challenges for scaling-up from suburb to large urban park system include the ambiguity in park classification resulting from a greater diversity in parks and reserves across the system and sampling for larger and more heterogeneous human populations.

The first study innovation was to simplify the list of park activities to assess physical health benefits based on metabolic equivalent of task (MET). Metabolic equivalents are a unit used to estimate the metabolic cost of physical activity, with the value of one MET being approximately equal to an individual's resting energy expenditure (Jette, Sidney, & Blümchen, 1990). METs can be estimated for a range of physical activities based on the nature and the intensity of engagement in the activity. Park activities that could be mapped ranged from low energy, sedentary activities such as sitting, to higher energy activities such as running, cycling, and playing sport. The list of activity markers included new activities not previously used (*dog walking*, *water-based activities*, and *supervising children in parks*). As a design trade-off for simplicity in mapping, multiple MET levels (e.g., high, medium, low) were not provided for each activity as in the previous study even though most activities have varying MET intensity levels.

A second innovation was an effort to capture the frequency and duration of the mapped park activity. The intent was better estimate the physical benefits associated with the activities. A third innovation was adapt and modify the NRPA ((Mertes & Hall, 1996) park classification typology criteria to the operational demands of larger, variable, and more complex urban park system.

Thus, this study seeks to answer research questions about the applicability of suburb-level findings about park benefits to a large urban park system as well as methodological questions about scaling-up the participatory methods.

The following research questions assess the distribution of park benefits within a large urban park system:

(1) What types of parks/reserves offer more (less) physical health benefits in an urban park system?
(2) Can the mapping of physical activities based on assumed MET levels provide reliable estimates of physical health benefits from different types of parks?
(3) How are multiple park benefits (environmental, physical, psychological, and social) distributed by park type and which types of parks offer disproportionately more (less) of these benefits?
(4) Does the diversity of park activities and benefits differ by park type and size?
(5) Is the distribution of physical activities and benefits related to distance from domicile?

The following research questions identify key issues in scaling-up participatory mapping methods to a large urban park system:

(6) How do population sampling methods (household vs. voluntary) in participatory mapping influence demographic and geographic representativeness of findings about urban park benefits?
(7) What geographic and social factors should be considered in classifying and analysing urban parks by park type for examining the distribution of benefits in a large and diverse system?

Following the answers to these questions, we discuss the strengths and limitations of participatory mapping as social research method for identifying urban park and greenspace benefits and how the method can be better applied to inform urban greenspace management.

2. Methods

2.1. Study location

The geographic setting for this study was Brisbane, Australia, the capital city of Queensland with an estimated greater metropolitan area population of 2.35 million people. The Brisbane local government area (LGA), the physical boundary for this study, has an estimated population of 1.2 million and encompasses 1338 km^2 (ABS, 2015). The Brisbane City Council (BCC) manages the hundreds of parks and reserves located in the LGA that range in size from small neighborhood parks to large district parks, including two botanic gardens.

2.2. Sampling and data collection

The data collection portion of study was completed between October 2016 and January 2017. Two sampling methods were used to recruit participants to the internet-based participatory mapping (PPGIS) study:

(1) *Random household participants:* Residential mailing addresses for the Brisbane City Council LGA were obtained from a commercial vendor (yell123.com). A total of 5000 household addresses were randomly sampled from the address database stratified across suburbs with weightings proportional to the area of each suburb. A letter of invitation to participate in the study was sent on October 7, 2016 with a follow-up reminder postcard sent on October 18, 2016. An additional 2500 household addresses were randomly selected using the same protocol as above and sent recruitment letters on October 24, 2016. No additional follow-up reminders were sent to this latter sample. Responses from this household sampling group were tracked by unique access code. To encourage participation, an incentive was offered consisting of a $10 gift voucher to a grocery/department store chain located throughout the greater Brisbane area. Alternatively, participants could select from one of three local charities who would receive a $10 donation on the participant's behalf at the close of the study.
(2) *Volunteer participants:* The BCC sent an announcement of the study to community groups with potential interests in BCC parks via the *Greenheart Newsletter* mailing list. Community groups also advertised the survey through their own social networks, via Twitter and Facebook. The announcement contained the URL address of the study website. Volunteer participants were assigned different access codes from the household sample and tracked separately and were not offered an incentive for participation.

2.3. PPGIS methods and process

The research team developed an initial PPGIS survey based on previous research by Brown et al. (2014) and met with BCC professional staff responsible for park/reserve management to refine the list of activities and benefits to be included in the study. The survey was pretested with a convenience sample of colleagues of the research team and with BCC staff.

The PPGIS survey website contained four primary components: (1) an initial screen for study participants to enter their supplied access code (household sample) or to request a dynamic access code (volunteer sample); (2) a screen to obtain informed consent; (3) customized Google® maps interface instructing the participant to drag and drop different digital markers onto a map of the Brisbane LGA area; and (4) a set of text-based survey questions that followed the mapping activity. The digital markers for mapping activities and benefits were located in panels on the left of the screen where participants would drag and drop markers onto the map location representing the activity or benefit. The first panel consisted of 12 physical activities commonly associated with parks and greenspaces and the second panel consisted of 12 potential park benefits.

The physical activities were identified and selected to provide a range of physical activities for assignment to a metabolic equivalent of task (MET) category based on an assumed level of energy expenditure for the activity. Because a given activity (e.g., walking) can be done at multiple intensity levels, we made an assumption about the most common level of intensity associated with the activity for classification into the nominal categories of *high*, *medium*, or *low* energy expenditure. For example, walking activity can be done at multiple intensity levels (walking speeds) with estimated MET levels ranging from about 2 to over 5 (Jette et al., 1990). In this study, walking activity was classified as a *moderate* level MET activity while resting/sitting was classified as a *low* MET activity. The 12 physical activities and their assigned MET categories appear in Table 1. The 12 activities were equally distributed (n = 4) among the three physical intensity categories of *high*, *medium*, and *low*.

The park benefits for mapping were based on recreation experience items developed by Driver, Tinsley, and Manfredo (1991) who identified 19 benefit domains that were reduced to 12 items and used in the Brown et al. (2014) urban park study. These items were as follows: enjoy nature, get exercise/fitness, escape stress, enjoy tranquility, spend time with friends, observe nature, be around good people, do

Table 1
List of markers (icons) for park activities and benefits used in the mapping application. Activity markers were classified into one of three physical intensity levels (Low, Moderate, High) based on assumed MET levels associated with the activity. Park benefits were classified into one of four benefit types (Physical, Environmental, Psychological, and Social).

Activity markers	Physical Intensity Level	Benefit markers	Type
Walking	Moderate	Enjoy nature	Environmental
Running or jogging	High	Get exercise/ fitness	Physical
Cycling	High	Escape stress	Psychological
Play sport	Moderate	Enjoy tranquility	Psychological
Resting/sitting	Low	Spend time with friends	Social
Social activities	Low	Observe nature	Environmental
Dog walking	Moderate	Be around good people	Social
Supervise children playing	Low	Do something creative	Psychological
Observe nature/ wildlife	Low	Connect with family	Social
Water activities	Moderate	Place to think/ reflect	Psychological
Use exercise equipment	High	Rest/relax	Psychological
Boot camp/fitness program	High	Spending time outside	Environmental

something creative, connect with family, place to think/reflect, place to rest/relax, and spending time outside. These benefits were classified into four groups based on the work of Moore and Driver (2005: p. 29): psychological, physical health (a subset of psychophysiological benefits), environmental, and social benefits.

Study participants were requested to identify activities they did in green space over the past two weeks in the Brisbane LGA. Upon marker placement, a pop-up window asked for the frequency and duration of the activity. No time period was specified for the mapping of benefits. To ensure spatial precision in marker placement, markers could only be placed when the Google® maps zoom level was 17 which approximates a 1:4500 map scale. Participants were encouraged to place at least 20 markers (activities + benefits).

Following the mapping activity, participants were redirected to a set of text-based survey questions that collected more information about their greenspace use and sociodemographic information for comparison with census data.

2.4. Data analysis

The spatial data (location and marker type) and non-spatial data (responses to survey questions) were analyzed using ArcGIS® (v10.4) and SPSS® (v24) software. Markers placed outside the study area boundary were excluded from analyses as the focus of this study was park activities and benefits within the Brisbane City Council (BCC) local government area. A total of 8763 physical activity and benefit markers were available for analyses.

To assess the spatial representativeness of participants within the study area, we compared the proportion of people living in each postcode area using ABS census data (2011) with the proportion of participants in each area. The expected (census) vs. observed (participants) proportions were used to calculate z scores for statistical inference. For example, if a postcode contained 3% of the Brisbane population, and the participant proportion for the postcode was 1%, the postcode would be spatially under-represented. We also assessed spatial representativeness based on the number of points mapped rather than the number of participants. Significant under- or over-represented postcodes were plotted on a map of the study area to indicate potential spatial bias.

To analyze the level of physical activity and types of park benefits

Table 2
Park classifications used in this study adapted from NRPA classifications (Mertes & Hall, 1996).

NRPA Classifications	NRPA Size & Location Guidelines	Classification in this study	Operational definition for BCC	Number (%) of activity/ benefit markers[a]	Number of unique units
Mini-park	Mini-park—between 2500 sq. ft. and one acre, < 1/4 mile in residential setting	Mini-park (1)	Parks/reserves < 0.4 ha	241 (3%)	88
Neighborhood park	Neighborhood—5 to 10 acres optimal, 1/4 to 1/2 mile distance	Neighborhood (2)	Neighbourhood—0.4 to 4 ha	1162 (13%)	297
Community park	Community—usually between 30 and 50 acres, 1/2 to 3 mile distance	Community (3)	Community—between 4 and 20 ha	1836 (21%)	171
Large urban park	Large Urban Park—usually a minimum of50 acres with 75 or more acres optimal, usually serves entire community	Large Urban (4)	Large—between 20 and 50 ha	598 (7%)	41
School	School-park—variable size, location determined by school	School (5)	School grounds—variable in size, identified as educational facility (includes both state and private schools)	109 (1%)	21
Special Use Sports Complex	Special use—size variable, location variable Sports complex—usually a minimum of 25 acres with 40–80 acres optimal, strategically located	Sports (6)	Minimum of 10 ha, dominated by sporting facilities, with little natural vegetation.	80 (1%)	8
Natural Resource Areas	Natural resource areas—size variable, location depends on availability and opportunity	Natural park (7)	Natural resource areas—greater than 50 ha, dominated by natural vegetation	1510 (17%)	35
Park Trails/Connector Trails	Trails–.5 miles per 1000 (1983 NRPA standard), location variable	Linear park (8)	Size and location variable; mostly along waterways in BCC	2257 (25%)	184

[a] There were 1133 markers (13%) that did not fall within a park or school boundary.

occurring within the greater Brisbane area, parks and reserves were classified based on an adapted NRPA park typology (Mertes & Hall, 1996). Table 2 shows the NPRA classifications and the operational definitions used in this study. Parks were classified into one of eight mutually exclusive categories: (1) Mini-parks consisting of parks/reserves less than 0.4 ha in size; (2) Neighborhood parks that ranged in size between 0.4 and four hectares; (3) Community parks ranging between 4 and 20 ha; (4) Large urban parks ranging between 20 and 50 ha; (5) Schools with greenspaces that are potentially accessible to the public; (6) Sports parks/complexes designed primarily for sporting activities such as football/cricket ovals and that contain relatively little native vegetation; (7) Natural parks that are greater than 50 ha in size and dominated by native vegetation; (8) Linear parks consisting of parks along the Brisbane River, other creeks and tributaries, and coastal strips. The majority of these linear parks contained connecting trails.

To prepare the data for analysis, physical activity and benefit markers (8763) were spatially intersected with park/reserve boundaries, of which (13%) were located outside formally designated parks/reserves/schools. The remainder of the markers (87%) were classified into 845 parks/schools out of 2350 park/schools in the study boundary area.

2.4.1. Associations between physical park activities, park type, and park size

The 12 activity markers were spatially intersected with the parks located in the greater Brisbane area. Activities not falling within any park, reserve, or school boundary were classified as "outside". The activity markers were classified into one of three physical intensity categories based on an assumed MET level: (1) *low* intensity activities were associated with sitting, standing, and observing behavior; (2) *moderate* intensity activities were associated with walking, water-based activities, or playing sport; (3) *high* intensity activities were those associated with running/jogging, cycling, or fitness/boot camp. The park activities were cross-tabulated by park type to generate chi-square statistics and adjusted standardized residuals. Chi-square residuals assess the strength of association between two categorical variables following a statistically significant chi-square result. A standardized residual is the difference between the observed frequency and the expected frequency divided by the standard error of the residual. Standardized residuals provide a normalized score like a *z* score, and if greater than $+2.0$, indicate significantly more activities than would be expected, while standardized residuals less than -2.0 indicate fewer activities than expected.

To assess the potential relationships between park size, park type, and the physical health benefits associated with park activities, Pearson's product moment correlation was calculated between physical activity scores and park size for each park that contained a minimum of five or more mapped activities. The physical activity score was calculated for each park by summing the products of mapped park activities multiplied by the nominal MET category for the activity. For example, if a park had two resting/sitting activity markers (MET category 1), two walking markers (MET category 2), and one jogging marker (MET category 3), the physical activity score for the park would be ($2 \times 1 + 2 \times 2 + 1 \times 3 = 9$). The physical activity scores for each park were plotted by park type.

To assess whether the potential influence of park size on mapped activities was significant, we ran a general linear model with the number of mapped activities and the physical activity scores as dependent variables, park type as the independent variable, and park size as a model covariate.

2.4.2. Associations between park benefits, park type, and park size

The 12 park benefit attributes were grouped into four types of benefits: (1) *physical* (get exercise/fitness); (2) *environmental* (enjoy nature, observe nature, spend time outside); (3) *psychological* (escape stress, enjoy tranquility, rest/relax, think/reflect, do something creative; and (4) *social* (spend time with friends, be around good people, connect with family) and spatially intersected with parks in study area. Cross-tabulations were generated with the chi-square statistic and standardized residuals to determine significant associations between park type and benefit classifications. The relationship between park size, measured in hectares, and the number of mapped park benefits was analyzed using Pearson's product moment correlation for each park with five or more mapped benefits. The results were graphically plotted by park type.

To assess whether the influence of park size on mapped benefits was significant, we ran a general linear model with the number of mapped benefits as a dependent variable, park type as the independent variable, and park size as a covariate.

2.4.3. Diversity of physical activities and benefits by park type and size

We analysed the diversity of activities and benefits by park type using the Shannon diversity index (Shannon, 1948) for all parks with five or more activities and benefits. The Shannon diversity index accounts for both the abundance and evenness of mapped attributes with index values typically falling within the range of 1.5–3.5. Larger index values indicate greater diversity of activities or benefits for a given park. The diversity of park activities and benefits was calculated as follows:

$$-\Sigma p_i \ln p_i$$

where p_i, is the proportional abundance of the *i*th park attribute (activity or benefit) = (n_i/N).

The Shannon index values were calculated for both physical activities and benefits. Spearman rank correlation coefficients were calculated between park size and the diversity indices for all park types combined and for individual park types. A one-way analysis of variance (ANOVA) was performed to determine whether mean diversity indices for activities and benefits differed by park type. Brown (2008) previously found larger urban parks to have a greater diversity of values for urban residents.

2.4.4. Distribution of activities and benefits as a function of distance from domicile

Study participant domicile locations were geocoded from addresses (household sample) or estimated based on the location of the street intersection nearest their home (volunteer sample). The Euclidean distance was calculated in GIS from domicile to each physical activity and benefit. A one-way analysis of variance (ANOVA) was performed to determine the mean distances of mapped activities and benefits to participant domicile and whether these differences were statistically significant.

2.4.5. Spatial distribution of park benefits

To visualize the spatial distribution of park benefits within the Brisbane study area, we categorized each park with two or more mapped benefits (n = 355) and classified each according to the most frequently mapped benefit category (physical, environmental, psychological, and social). The parks were symbolized by total number of benefits and benefit type and plotted on a map of the study area using park centroids. To augment visual analysis, we calculated the observed mean distance and the nearest neighbor ratio (R) for each class of parks by benefit category to measure the relative clustering and spatial dispersion of parks.

3. Results

3.1. Participant characteristics

A total of n = 816 study participants mapped one or more spatial attributes in the study resulting in 11,421 mapped attributes, of which

11,187 were located inside the study area. Of this total, there were 8763 activity and benefit markers. Markers for park improvements were also mapped in the study but were not included in the analyses. There were a total n = 719 full survey completions where participants mapped locations and answered the text-based survey questions following the mapping activity. Study participants were divided between random household sample respondents (n = 541) and volunteer participants (n = 275). The response rate for the random household sample was about 8% (541/7096) after accounting for non-deliverable recruitment letters. For the volunteer sample, it is not possible to calculate a traditional response rate. Other internet-based, PPGIS studies of the general public using probability household surveys have reported about a 10% response rate (Pocewicz, Nielsen-Pincus, Brown, & Schnitzer, 2012) or more recently, a 12% response rate using a similar method in Australia that included multiple follow-up reminders (Karimi, Brown, & Hockings, 2015).

With respect to mapping behavior, the volunteer sampling group mapped significantly more activity and benefit markers on average than the household sampling group (t-tests, $p < 0.05$). For specific activity categories, volunteers mapped significantly more "play sport", "social activities", "dog walking", "observing nature/wildlife", and "water activities" than the household sample (*t*-tests, $p < 0.05$). With respect to benefit categories, volunteers mapped significantly more "get exercise/fitness", "enjoy tranquility/avoid crowds", "spend time with friends", "observe/study nature", "be around good people", "do something creative", and "connect with family markers" ($p < 0.05$).

We compared study participant demographic variables with census data from the greater Brisbane area (ABS, 2011) to assess participant representativeness of the Brisbane population (see Table 3). About 49% of participants were female (ABS census = 51%) with a median age of 53 (ABS census = 35) and an age range of 18–87 years. About 43% of participants were in families with children (ABS census = 45%). About 68% of participants reported formal education attainment of a Bachelor's degree or postgraduate education (ABS census = 20%) and about 27% reported weekly income of $2000 or more (ABS census = 7%). Thus, the Brisbane participant samples, both random household and volunteer, were biased toward older participants with higher levels of formal education and income than the general Brisbane population. The sampling bias toward older, more highly educated, and higher income levels and is consistent with other reported PPGIS studies (Brown & Kyttä, 2014).

From the survey questions, study participants have lived in the Brisbane area for an average of 31 years. Over 50% of participants rated their knowledge of Brisbane parks/reserves and other greenspaces as "excellent" or "good" with about 40% rating their knowledge as "average". Less than 2% rated their knowledge as "poor". In terms of park/reserve use frequency, about 78% of participants use parks at least once a week with another 9% using the parks at least once every two weeks or once a month (5%).

The spatial representativeness of participants were assessed by comparing the proportion of participants by postcode with the proportion of Brisbane residents living in the postcode as reported in census data. Significant deviations in postcode proportions with z scores greater than +2.0 or less than −2.0 were plotted on a map (see Fig. 1). There was some spatial bias toward greater participation in four postcodes (indicated in green), and disproportionately less participation in one postcode area (indicated in red). Analysis based on the proportion of total activity and benefit points mapped rather than the number of participants indicated that three postcodes were over-represented. Thus, spatial bias in response was relatively low with most study participants spatially distributed across the study area in rough proportion to the overall population.

3.2. Relationships between physical activities, park type, and park size

There was a statistically significant association between physical activity markers (coded as *low*, *moderate*, and *high* MET intensity) and park type for all respondents ($X^2 = 82.9$, df = 16, $p < 0.001$) and for the household ($X^2 = 38.8$, df = 16, $p < 0.001$) and volunteer ($X^2 = 58.5$, df = 16, $p < 0.001$) samples respectively (Table 4). The largest number of *high* MET activities were associated with linear parks for all sampling groups, followed by community parks. The proportion of *high* MET activities was also significantly larger than expected outside formal park boundaries (residuals greater than +2.0), a logical result given that high MET activities such as jogging and cycling often include geographic areas outside of park boundaries as part of the activity. The smaller urban park classes—mini-park and neighborhood—contained more *low* MET activities and fewer *high* MET activities than would be expected based on chi-square residual values.

The relationship between physical activities, park type, and park size was further examined by plotting aggregated physical activity scores by park type and size for parks with more than five mapped activities (Fig. 2). The bivariate correlation between activity score and park size was significant, but moderate in strength ($r = 0.41$, $p < 0.05$) suggesting larger parks provide more opportunities for physical activities and associated health benefits. When park size was treated as a covariate in a general linear model (GLM) with aggregated activity score as the dependent variable and park type as the independent variable for parks with more than five mapped activities (n = 216), the model was significant ($F = 3.5$, $p < 0.001$) but weak ($R^2 = 0.11$). The park size covariate was not significant in the model ($p > 0.05$). Natural parks had the largest mean activity scores, followed by linear parks, and then large urban parks. The lowest mean activity scores were found in mini-parks. When the model was run on

Table 3
Participant profile and statistics.

	All	Household	Volunteer
Number of participants (mapped one or more locations)	816	541	275
Number completing post-mapping survey	719	496	223
Number of locations mapped	11,421	6326	5095
Range of locations mapped (minimum/maximum points)	1–138	1–98	1–138
Mean (median) of all markers mapped[1]	14.0 (9.0)	11.7 (8)	18.5 (12)
Mean (median) of activities mapped[1]	5.7 (4.0)	5.0 (3.0)	6.9 (5.0)
Mean (median) of best places mapped[1]	5.4 (2.0)	4.5 (2.0)	7.1 (2.0)
Mean (median) of actions mapped[1]	3.0 (0.0)	2.2 (0.0)	4.5 (1.0)
Knowledge of places (%)			
Excellent	9.3	6.7	15.2
Good	40.9	38.8	45.7
Average	39.6	42.8	32.3
Below average	8.8	10.1	5.8
Poor	1.4	1.6	.9
Years lived in Brisbane (mean)	30.9	32.5	27.5
Gender (ABS, 2011: Male 49.3%)			
Female (%)	48.5	45.1	56.1
Male (%)	51.5	54.9	43.9
Age in years (mean/median) (ABS, 2011: median 35)	52.1/53.5	53.9/55	48.1/47
Education (%) (ABS, 2011: 20.2% Bachelors/postgraduate)			
Less than Bachelors	32	35	26
Bachelor's degree/postgraduate	68	65	74
Income (weekly) (ABS, 2011: 7% $2000 or more)			
$2000 or more (%)	27	28	23
Lifecycle (%) (ABS, 2011: 45%)			
Couple family with children	43	45	41
Frequency of park use (%)			
At least once per week	78	75	85
At least once per fortnight	9	10	8
At least once per month	5	6	3
Less than once per month	8	9	4

[1] Mean differences in the number of markers mapped by household and volunteer groups are statistically significant (*t*-tests, $p < 0.05$).

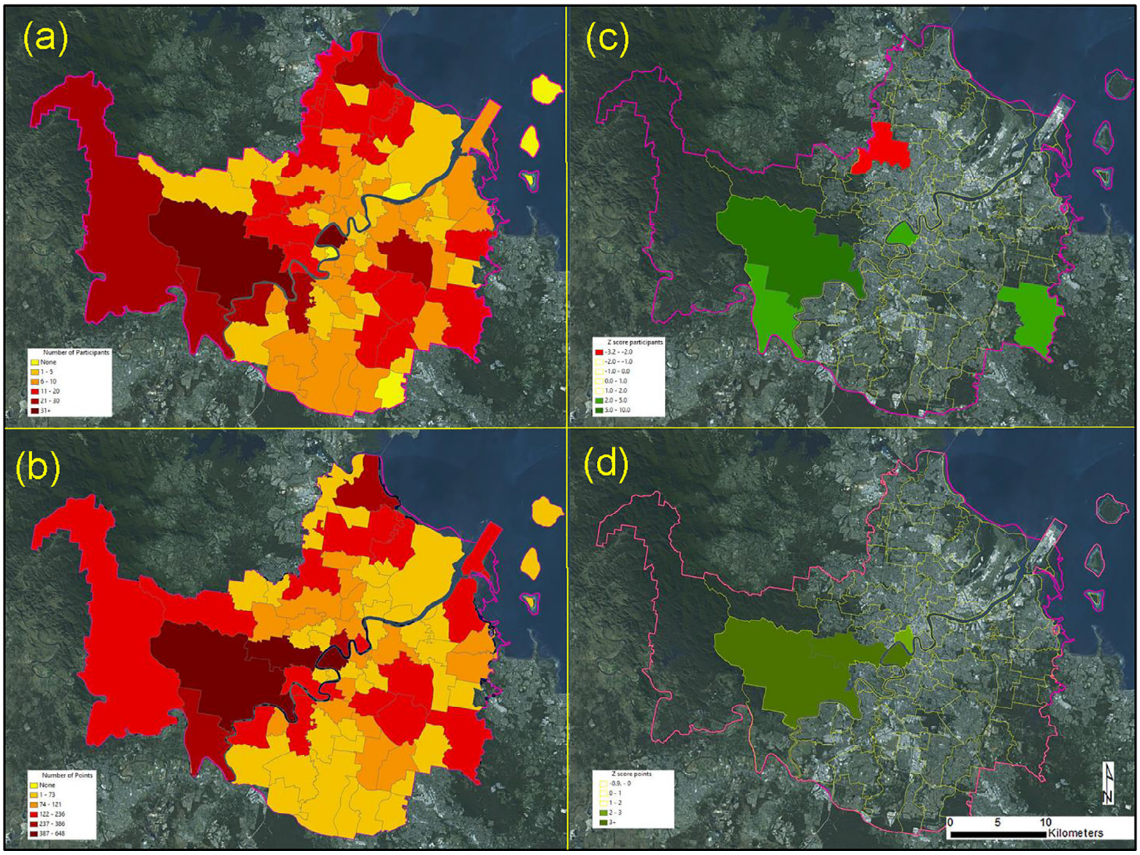


Fig. 1. Distribution of (a) number of participants and (b) mapped points (activities and benefits) by postcode area in Brisbane. Z scores indicate whether number of participants (c) and points (d) are significantly greater (green) or less than expected (red) based on population proportions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Cross-tabulation of physical activity level by park type showing the number and percentage of activity markers with adjusted standardized chi-square residuals for all participants and for two sampling groups (random household and volunteer). Adjusted standardized residuals +2.0 or greater (green) indicate more activity markers than expected and standardized residuals −2.0 (pink) or less indicate fewer markers than expected.

	Physical activity level (all respondents)[a]				Physical activity level (Household)[b]				Physical activity level (Volunteer)[c]			
Park Type	Low	Moderate	High	Total	Low	Moderate	High	Total	Low	Moderate	High	Total
Outside of park	130	291	165	586	74	218	104	396	56	73	61	190
	10.4%	14.2%	15.6%	13.4%	11.6%	15.7%	19.2%	15.4%	9.2%	11.0%	11.8%	10.6%
	-3.7	1.3	2.4		-3.1	.4	2.7		-1.4	.4	1.1	
Mini-park	53	66	20	139	30	50	11	91	23	16	9	48
	4.2%	3.2%	1.9%	3.2%	4.7%	3.6%	2.0%	3.5%	3.8%	2.4%	1.7%	2.7%
	2.5	.1	-2.8		1.8	.2	-2.1		2.0	-.5	-1.6	
Neighborhood park	231	322	103	656	114	217	58	389	117	105	45	267
	18.5%	15.7%	9.7%	15.1%	17.9%	15.6%	10.7%	15.2%	19.1%	15.8%	8.7%	14.9%
	4.0	1.1	-5.5		2.2	.7	-3.3		3.6	.8	-4.7	
Community park	274	427	183	884	143	292	102	537	131	135	81	347
	21.9%	20.8%	17.3%	20.3%	22.4%	21.0%	18.8%	20.9%	21.4%	20.4%	15.7%	19.4%
	1.7	.8	-2.8		1.1	.2	-1.4		1.6	.8	-2.5	
Large urban park	65	117	60	242	32	75	27	134	33	42	33	108
	5.2%	5.7%	5.7%	5.6%	5.0%	5.4%	5.0%	5.2%	5.4%	6.3%	6.4%	6.0%
	-.6	.4	.2		-.3	.5	-.3		-.8	.4	.4	
Schools	20	31	18	69	5	14	3	22	15	17	15	47
	1.6%	1.5%	1.7%	1.6%	0.8%	1.0%	0.6%	0.9%	2.5%	2.6%	2.9%	2.6%
	.1	-.4	.4		-.2	.9	-.9		-.3	-.1	.5	
Sports park	13	27	10	50	9	16	9	34	4	11	1	16
	1.0%	1.3%	0.9%	1.1%	1.4%	1.2%	1.7%	1.3%	0.7%	1.7%	0.2%	0.9%
	-.4	1.0	-.7		.2	-.8	.8		-.8	2.6	-2.0	
Natural park	152	248	144	544	74	175	63	312	78	73	81	232
	12.2%	12.1%	13.6%	12.5%	11.6%	12.6%	11.6%	12.2%	12.7%	11.0%	15.7%	13.0%
	-.4	-.7	1.3		-.5	.8	-.4		-.2	-1.9	2.2	
Linear park	311	522	354	1187	156	331	165	652	155	191	189	535
	24.9%	25.5%	33.5%	27.2%	24.5%	23.8%	30.4%	25.4%	25.3%	28.8%	36.7%	29.9%
	-2.2	-2.5	5.2		-.6	-2.0	3.0		-3.0	-.8	4.0	
Total markers	1249	2051	1057	4357	637	1388	542	2567	612	663	515	1790
	28.7%	47.1%	24.3%		24.8%	54.1%	21.1%		34.2%	37.0%	28.8%	

[a]Overall association is significant ($X^2 = 82.9$, df = 16, $p < 0.001$).
[b]Overall association is significant ($X^2 = 38.8$, df = 16, $p < 0.001$).
[c]Overall association is significant ($X^2 = 58.5$, df = 16, $p < 0.001$).

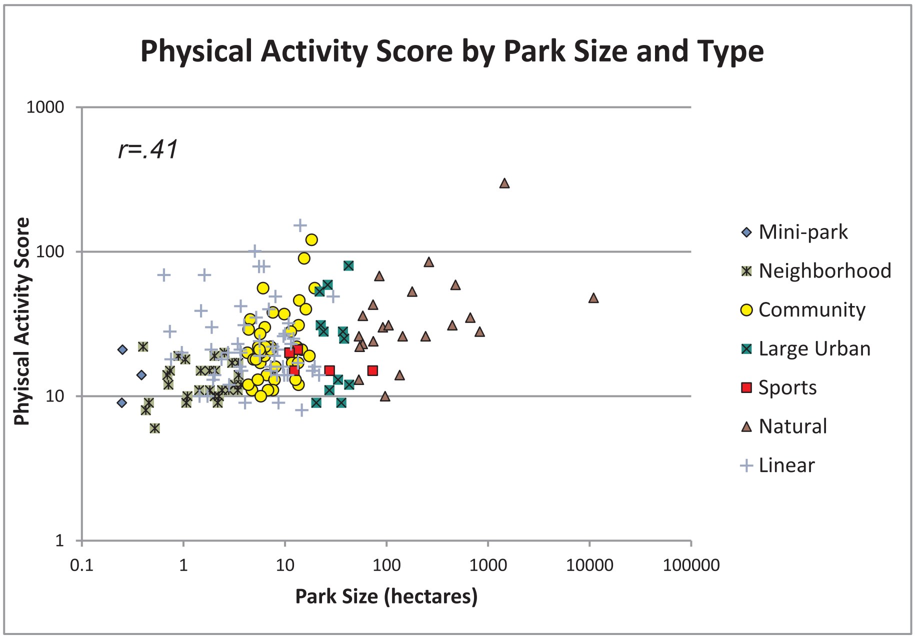


Fig. 2. Relationship between aggregated physical activity scores by park type and park size (hectares). Each activity was multiplied by associated MET intensity level category (low = 1, moderate = 2, high = 3) to calculate physical activity score. Parks with greater than five mapped activities were used in the calculation.

the number of activities as the dependent variable rather than the aggregated MET activity score, and all parks were included in the analysis regardless of the number of activity markers (n = 755), the model was significant ($F = 17.4$, $p < 0.001$, $R^2 = .140$) with park size being a significant covariate ($p < 0.05$). Thus, the number of physical activities mapped appears significantly related to park size, with fewer activity markers, on average, being placed in the large number of mini- and neighborhood parks across Brisbane.

3.3. Relationships between park benefits, park type, and park size

There were statistically significant associations between benefit markers and park type for all respondents ($X^2 = 120.1$, df = 24, $p < 0.001$) and for the household ($X^2 = 85.3$, df = 24, $p < 0.001$) and volunteer ($X^2 = 75.1$, df = 24, $p < 0.001$) samples respectively (Table 5). Environmental benefits were over-represented in natural parks while physical benefits were over-represented in linear parks as indicated by residuals greater than +2.0. Environmental benefits were under-represented in linear parks and social benefits were under-represented in natural parks (residuals < −2.0). Community parks were over-represented with social benefits.

The relationship between park benefits, park type, and park size was further examined by plotting the number of benefits by park type and size for parks with five or more mapped benefits (Fig. 3). Natural parks had the largest mean number of mapped benefits, followed by large urban parks, and community parks. The lowest mean number of benefits was found in sports parks. The bivariate correlation between the number of mapped benefits and park size was significant, but moderate in strength ($r = 0.52$, $p < 0.05$). When park size was treated as a covariate in a general linear model (GLM) with the number of benefits as the dependent variable and park type as the independent variable for parks with five or more mapped benefits (n = 176), the model was significant ($F = 4.5$, $p < 0.000$, $R^2 = 0.16$). The park size covariate was significant ($p = 0.079$) at the 0.10 level of significance in the model.

3.4. Diversity of activities and benefits by park type and size

We examined the diversity of activities and benefits by park type using the Shannon diversity index. For all park types combined, there were significant bivariate rank correlations between the diversity of activities and park size ($r = 0.56$, $p < 0.001$) and diversity of benefits and park size ($r = 0.49$, $p < 0.001$). Within a specific park type, there were significant correlations with park size between activity diversity and community parks ($r = 0.43$, $p < 0.01$), large urban parks ($r = 0.78$, $p < 0.001$), sports parks ($r = 0.97$, $p < 0.01$), natural parks ($r = 0.58$, $p < 0.01$), and linear parks ($r = 0.60$, $p < 0.001$). Benefit diversity was significantly correlated with park size for community parks ($r = 0.59$, $p < 0.001$), large urban parks ($r = 0.55$, $p < 0.05$), and linear parks ($r = 0.30$, $p < 0.05$).

We used ANOVA with Tukey HSD post hoc tests to examine pairwise comparisons of mean activity diversity by park type. Neighborhood park activity diversity was significantly lower than all other park types ($p < 0.05$), with all other park types being similar in mean diversity ($p > 0.05$). For benefit diversity, neighborhood park diversity was significantly lower than all other park types ($p < 0.05$) and natural park diversity was significantly higher than all other park types ($p < 0.05$). Mean benefit diversity was similar for community, large urban, and linear parks.

3.5. Distribution of activities and benefits as a function of distance from domicile

We examined the distribution of activities and benefits as a function of distance from domicile. Mean distances were calculated from domicile to each type of mapped activity or benefit and an ANOVA model was used to assess whether mean distances from domicile varied by activity or benefit type. With respect to activities, the shortest mean distance was for using exercise equipment (1827 m) while the longest distance was for social activities (4811 m). An error plot for distances between domicile and all mapped activities appears in Fig. 4 with statistically significant differences indicated in the table below the plot (ANOVA, $p < 0.05$, Tukey HSD). For benefits, the shortest mean distance was for places to think/reflect (3582 m) and to get exercise (3586 m) and the longest distances was for nature study (6482 m) and spending time with friends (5389 m). The mean distances to benefits were logically consistent with mean distances to activities associated with the benefits. Specifically, the activities and benefits of getting

Table 5

Cross-tabulation of park benefit by park type showing the number and percentage of benefit markers with adjusted standardized chi-square residuals for all responses and two sampling groups (random household and volunteer). Adjusted standardized residuals +2.0 or greater (green) indicate more benefit markers than expected and standardized residuals −2.0 (pink) or less indicate fewer markers than expected.

	Benefit category (all respondents)[a]					Benefit category (Household)[b]					Benefit category (Volunteer)[c]				
Park Type	Phys	Environ	Psych	Social	Total	Phys	Environ	Psych	Social	Total	Phys	Environ	Psych	Social	Total
Outside of park	99	164	135	89	487	78	111	84	61	334	21	53	51	28	153
	12.8%	10.4%	11.1%	12.7%	11.4%	17.0%	12.8%	12.4%	17.0%	14.1%	6.6%	7.4%	9.4%	8.2%	8.0%
	1.3	-1.6	-.4	1.2		2.0	-1.4	-1.6	1.7		-1.0	-.7	1.4	.1	
Mini-park	14	37	27	12	90	12	27	20	10	69	2	10	7	2	21
	1.8%	2.3%	2.2%	1.7%	2.1%	2.6%	3.1%	2.9%	2.8%	2.9%	0.6%	1.4%	1.3%	0.6%	1.1%
	-.6	.8	.3	-.8		-.4	.4	.0	-.2		-.9	1.0	.5	-1.0	
Neighborhood park	75	145	155	75	450	54	87	99	28	268	21	58	56	47	182
	9.7%	9.2%	12.7%	10.7%	10.5%	11.8%	10.1%	14.6%	7.8%	11.3%	6.6%	8.1%	10.3%	13.7%	9.5%
	-.9	-2.2	2.9	.2		.3	-1.5	3.1	-2.3		-1.9	-1.6	.8	2.9	
Community park	136	316	273	180	905	78	171	138	88	475	58	145	135	92	430
	17.5%	20.0%	22.4%	25.7%	21.2%	17.0%	19.8%	20.3%	24.5%	20.1%	18.3%	20.3%	24.9%	26.9%	22.5%
	-2.7	-1.4	1.2	3.2		-1.9	-.3	.2	2.3		-1.9	-1.7	1.6	2.2	
Large urban park	56	137	91	54	338	22	68	50	27	167	34	69	41	27	171
	7.2%	8.7%	7.5%	7.7%	7.9%	4.8%	7.9%	7.4%	7.5%	7.1%	10.7%	9.7%	7.6%	7.9%	8.9%
	-.8	1.4	-.7	-.2		-2.1	1.1	.4	.4		1.2	.9	-1.3	-.7	
Schools	10	12	10	5	37	5	3	1	3	12	5	9	9	2	25
	1.3%	0.8%	0.8%	0.7%	0.9%	1.1%	0.3%	0.1%	0.8%	0.5%	1.6%	1.3%	1.7%	0.6%	1.3%
	1.4	-.6	-.2	-.5		2.0	-.8	-1.6	.9		.5	-.1	.9	-1.3	
Sports park	6	9	5	7	27	6	6	5	6	23	0	3	0	1	4
	0.8%	0.6%	0.4%	1.0%	0.6%	1.3%	0.7%	0.7%	1.7%	1.0%	0.0%	0.4%	0.0%	0.3%	0.2%
	.6	-.4	-1.2	1.3		.8	-1.1	-.7	1.5		-.9	1.6	-1.3	.4	
Natural park	168	443	246	79	936	89	224	132	33	478	79	219	114	46	458
	21.6%	28.1%	20.1%	11.3%	21.9%	19.4%	25.9%	19.4%	9.2%	20.2%	24.9%	30.7%	21.0%	13.5%	23.9%
	-.2	7.5	-1.7	-7.4		-.5	5.2	-.6	-5.7		.5	5.3	-1.9	-5.0	
Linear park	212	316	279	200	1007	115	168	150	103	536	97	148	129	97	471
	27.3%	20.0%	22.9%	28.5%	23.5%	25.1%	19.4%	22.1%	28.7%	22.7%	30.6%	20.7%	23.8%	28.4%	24.6%
	2.7	-4.2	-.7	3.4		1.3	-2.9	-.4	2.9		2.7	-3.0	-.5	1.8	
Total markers	776	1579	1221	701	4277	459	865	679	359	2362	317	714	542	342	1915
	18.1%	36.9%	28.5%	16.4%		19.4%	36.6%	28.7%	15.2%		16.6%	37.3%	28.3%	17.9%	

[a]Overall association is significant ($X^2 = 120.1$, df = 24, $p < 0.001$).
[b]Overall association is significant ($X^2 = 85.3$, df = 24, $p < 0.001$).
[c]Overall association is significant ($X^2 = 75.1$, df = 24, $p < 0.001$).

exercise was closest to domicile while the activities and benefits associated with nature and social activities were most distant from domicile (Fig. 5).

3.6. Spatial distribution of park benefits in the study area

Each park with two or more mapped benefits (n = 355) was classified according to the most frequently mapped benefit type (physical, environmental, psychological, and social), was plotted on a map, and nearest neighbor statistics were calculated. If there was a tie in the most frequently mapped benefit type, the park was classified by both benefit types. The most frequent park class by benefit type was “environmental” (n = 210) with a mean nearest neighbor of 1084 m and a nearest neighbor ratio of 0.81 ($z = -5.36$, $p < 0.001$). The least frequent park class by benefit was “social” (n = 22) with a mean nearest neighbor of 3340 m and a nearest neighbor ratio of 1.32 ($z = 2.85$, $p < 0.01$). Parks where physical benefits were most frequent (n = 48) had a mean nearest neighbor of 1524 m and a nearest neighbor ratio of 0.84 ($z = -2.17$, $p < 0.05$) while parks where psychological benefits were most frequent (n = 75) had a mean nearest neighbor of 1566 m and a nearest neighbor ratio of 0.85 ($z = -2.49$, $p < 0.05$). Visually, these results are shown in Fig. 6 with fewer and more spatially dispersed “social” parks (red) and a greater number and more clustered “environmental” parks (green). Parks where “psychological” benefits were most frequent (blue) were most proximate to the Brisbane central business district (CBD) while parks where “environmental” benefits were the most frequent type (green) are evident on the periphery of the Brisbane study area and coincide with natural forest parks in the western and northern reaches of the Brisbane urban area.

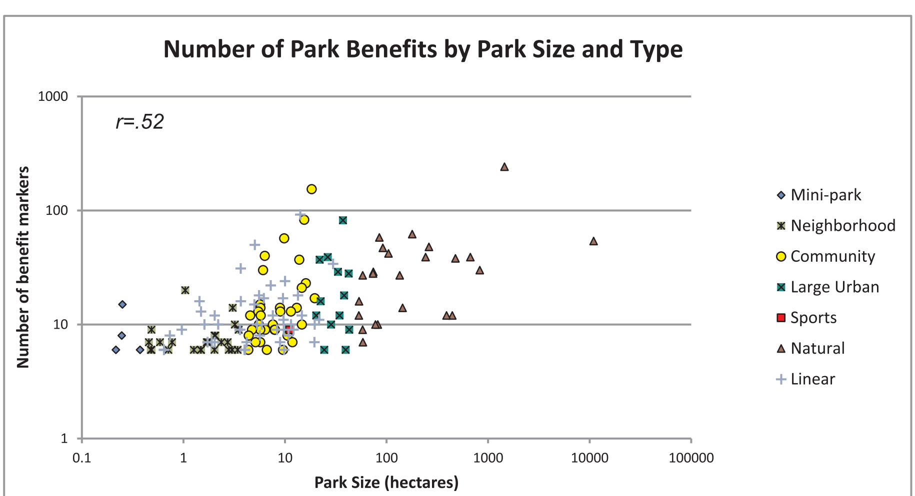
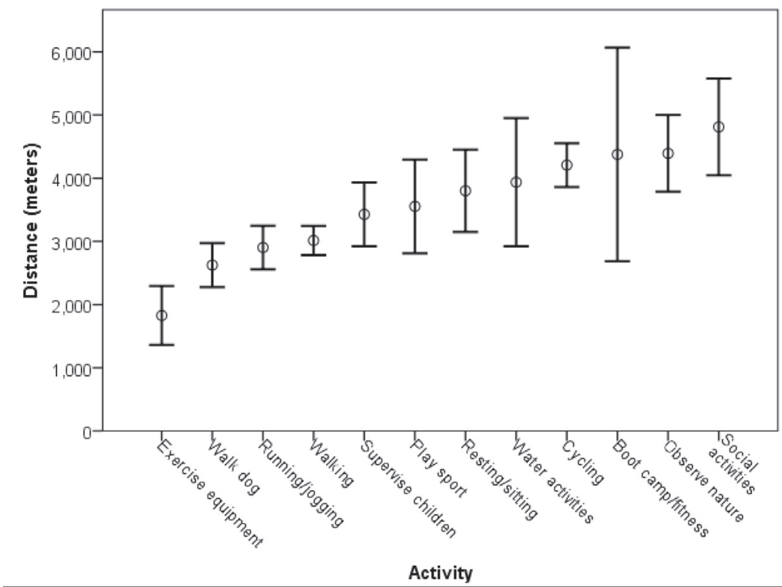


Fig. 3. Relationship between aggregated benefits by park type and park size (hectares). Parks with greater than five mapped benefits were used in the calculation.



	Walking	Running/ jogging	Cycling	Play sport	Resting/ sitting	Social activities	Dog walking	Supervise children	Observe nature/ wildlife	Water activities	Use exercise equipment	Boot camp/ fitness
Walking												
Running/jogging												
Cycling	*	*										
Play sport												
Resting/sitting												
Social activities	*	*	*		*							
Dog walking						*						
Supervise children						*						
Observe nature/wildlife	*	*					*					
Water activities					*							
Use exercise equipment						*			*			
Boot camp/fitness												

Fig. 4. Error bar plot showing mean distance (meters) and 95 percent confidence intervals for 12 activities from study participant domicile to mapped location with table showing activity distances that are significantly different (ANOVA, Tukey HSD, $p < 0.05$).

4. Discussion

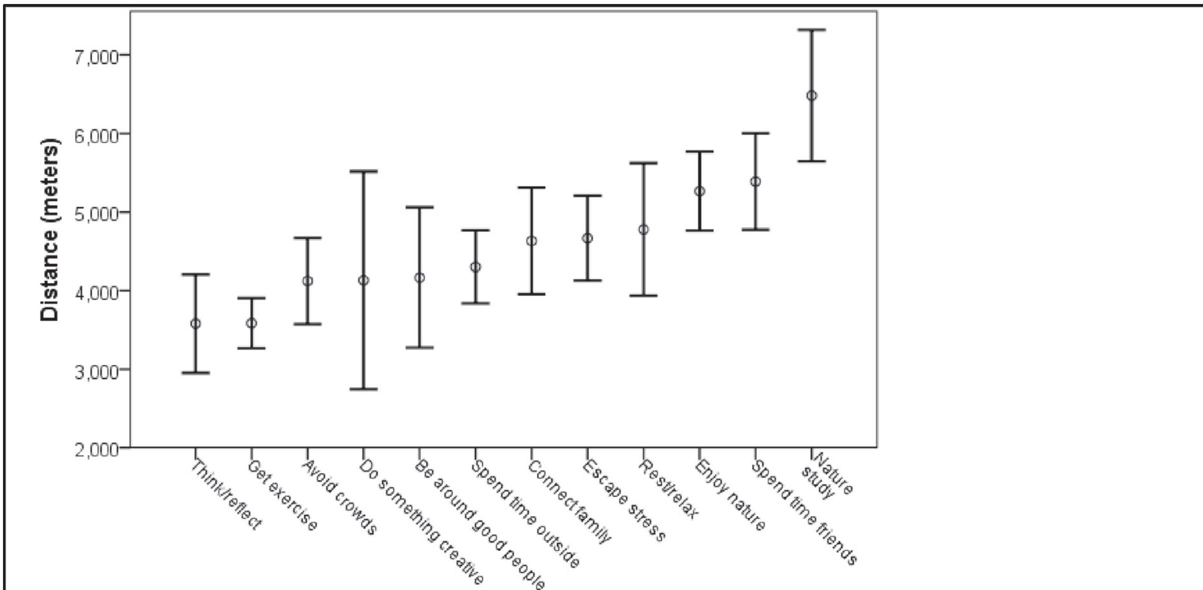
In this study, we evaluated the use of public participation GIS (PPGIS) methods to assess park benefits for a large urban park system (Brisbane, Australia). Previous research used participatory mapping methods to assess park benefits for a suburb located within the larger urban area of Adelaide, Australia (Brown et al., 2014). The scaling-up of the research to a large urban park system necessarily involved changes in research design and implementation with the potential to influence research outcomes. In addition to validating previous findings on the public benefits of different urban park types, we reflect on the challenges of scaling-up of participatory mapping research methods for a large and diverse urban park system.

4.1. Urban park classification and urban planning

One of the greatest challenges—and arguably—one of the most important with implications for both public benefit analysis and urban planning is the park classification system that describes the structure of urban park system (size, components, and spatial configuration). Classification systems have been guided by physical properties, park features, and the surrounding environment, an approach that is consistent with a planning standards approach to urban planning and design. However, an argument can be made that the provision of urban parks and greenspaces should also be equally informed by an understanding of the distribution of benefits provided by urban parks and greenspaces. The physical presence of parks and greenspaces does not guarantee that the imputed human benefits of parks are actually realized, nor equitably distributed, especially when park access is multidimensional with geographic proximity being just one factor among others (Wang, Brown, & Liu, 2015). Further, simply knowing the physical structure of an urban park system does not provide sufficient information for benefit trade-off analysis in decisions regarding the allocation of scarce urban space.

The Adelaide suburb research operationalized six classifications from the NRPA park typology (Mertes & Hall, 1996). The NRPA classification system uses the criteria of size, proximity, and function. For example, park types are classified primarily by their size, but some park classes also include proximity to residential areas as a criterion. Sports and recreation parks are identified by function to meet the requirements of the sporting/recreation activity (e.g., soccer fields). This Brisbane study also used the NRPA classification system as a foundation for identifying eight types of urban parks (including schools) primarily based on size, but also included other criteria such as physical shape, waterway contiguity, dominant park function, and the extent of native vegetation. Classifying sports parks in Brisbane posed a challenge because these parks may include other park features (e.g., natural areas) not associated with the sporting activity. Linear parks in this study were classified primarily based on their shape (i.e., elongated and narrow), but with additional consideration for contiguity with physical features such as waterways and the presence of connecting trails. The distinction between sports parks, large urban parks, and natural parks which overlapped in size required a subjective judgement about the dominant function of the park, combined with the extent of native vegetation. In short, classification of parks required some subjective analyst judgement when applying multiple criteria.

In scaling the research to a large urban park system that included over 2300 designated parks and reserves, we used objective GIS criteria to generate initial park classes, which were then visually assessed for possible reclassification. In our classification system, the park size break



	Enjoy nature	Get exercise	Escape stress	Avoid crowds	Spend time friends	Nature study	Be around good people	Do something creative	Connect with family	Think/ reflect	Rest/ relax	Spend time outside
Enjoy nature												
Get exercise	*											
Escape stress												
Avoid crowds												
Spend time friends		*										
Nature study		*	*	*								
Be around good people						*						
Do something creative												
Connect with family						*						
Think/reflect	*				*	*						
Rest/relax						*						
Spend time outside						*						

Fig. 5. Error bar plot showing mean distance (meters) and 95 percent confidence intervals for 12 benefits from study participant domicile to mapped location with table showing benefit distances that are significantly different (ANOVA, Tukey HSD, $p < 0.05$).

points that distinguish neighborhood from community parks lack definitive supporting rationale and empirically, the results were similar for these types of parks. Additional greenspace classification criteria such as those described by Kimpton (2017) that account for the presence and abundance of amenities such as facilities could augment the classification system, as can classification systems that account for additional variables such as land cover, built context, and social context (Ibes, 2015).

Historically, the planning for urban parks and greenspaces, to the extent that it has been intentional and proactive, has followed a standards approach based on ratios such as the amount of parkland per population. An enhanced standards approach, as found in the NRPA guidelines (Mertes & Hall, 1996), treats urban parks and greenspaces as a system and assumes that different types of urban parks and greenspaces provide differential human benefits within the system. Our mapping results provide empirical evidence that the systems approach to park classification embodied in the NRPA framework appears sound, even when applied to a large, complex urban park system such as Brisbane that is characterized by a high level of park diversity. The participatory mapping methods described in this study also assume a systems approach to understanding urban park benefits. The pairing of these two systems approaches (physical structure and social benefit structure) provides an evidence-base to inform future urban park planning. For example, in the Brisbane system, increasing physical health benefits would suggest investment in more linear parks (or greater trail connectivity in existing linear parks), increasing social benefits would suggest investment in community parks, and providing greater psychological benefit would suggest greater investment in neighborhood parks. The environmental benefits of parks and greenspaces already appear ubiquitous across the city.

4.2. Association of activities and benefits by park type, size, and distance

Consistent with previous research, we found that linear parks, in particular, provide significant health benefits because they provide opportunities to engage in higher intensity aerobic physical activities such as walking, running, and cycling. Given the nature of these activities, these were also mapped disproportionately outside formal parks and reserves. Linear parks play a significant role in facilitating these activities through trails that make these activities safer and more enjoyable. Our linear park results were not as strong as the Adelaide suburb research because Brisbane contains many more parks that were classified as linear based on shape and adjacency to waterways, but some of these parks lack developed trails that make them attractive for walking, running, or cycling longer distances.

The distribution of non-physical park benefits (psychological, environmental, and social) by type of park/reserve was also consistent with previous research. As a system, urban parks provide a full range of public benefits but the benefits appear differentially important based on park type. Natural parks provide disproportionately more environmental benefits while community parks provide disproportionately more social benefits. In this study, neighborhood parks emerged as providing disproportionately more psychological benefits (e.g., escape stress, rest/relax), a benefit/type association that was not significant in the previous study at the suburb scale.

Brown (2008) posited that the diversity of values people hold for parks increases with park size and the proximity of parks to denser urban populations. The Adelaide suburb-level study provided significant evidence for the importance of park size and park type to both physical activity and benefit diversity. In this study, park size and park type were also significantly related to activity diversity and benefit

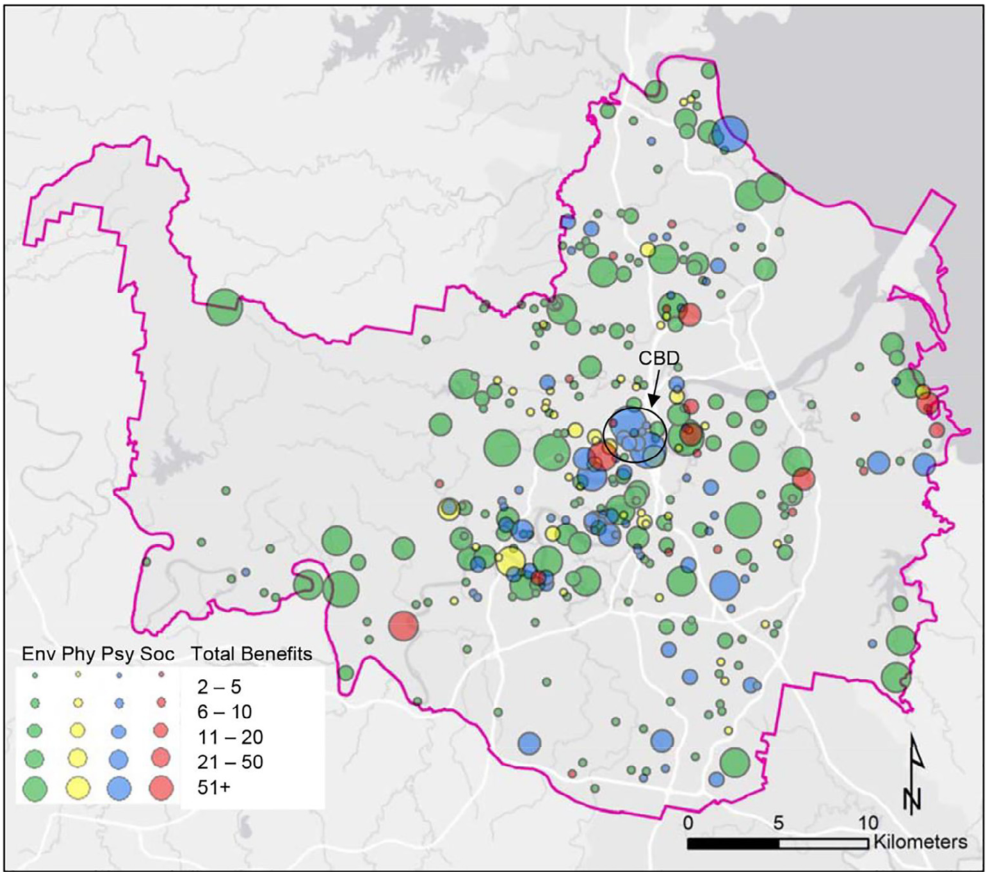


Fig. 6. Map showing the spatial distribution of benefits mapped in parks (displayed as centroids) with two or more mapped benefits. Colors show the most frequent benefit type in the park where Env = environmental, Phy = physical, Psy = psychological, Soc = social. CBD = Central Business District.

diversity, thus confirming the influence of park type and size when scaled-up to an urban park system with more parks and greater park variability. As a general principle, larger parks provide greater activity and benefit diversity. The diversity of park activities and benefits appear lower for parks such as neighborhood parks, and higher for natural parks.

With respect to distance analyses of activities and benefits to participant domicile, these study results were consistent with the Adelaide suburb study. Physical benefits were located most proximate to participant domicile while social benefits were more distant. Environmental benefits, primarily associated with natural parks, were located most distant from participant domicile which appears logical given the configuration of the park system in Brisbane where larger natural parks are located on the urban periphery. Lin et al. (2014) suggested that the motivation to visit parks and interact with nature in Brisbane is driven more by nature orientation—the affective, cognitive, and experiential relationship individuals have with the natural world—than the availability and proximity of parks. Our study did not measure affinity for nature so we cannot directly assess park use motivation on this variable. However, the opportunity for environmental benefits from parks and greenspaces does not appear to be a limiting factor as parks that provide environmental benefits are spatially distributed throughout the greater Brisbane area (Fig. 6).

Our results indicate that Brisbane park users do differentiate park benefits spatially based on park distance from domicile and appear willing to travel longer distances to obtain social and environmental benefits of urban parks in particular. However, the evidence for the importance of distance from domicile as a factor in explaining actual park use and associated benefits appears weak. For example, Schipperijn et al. (2010) did not find distance to greenspaces to be a limiting factor for the majority of the Danish population in explaining the frequency of greenspace use. In the U.S., distance to the closest park was not significantly related to either park use or park physical activity (Kaczynski et al., 2014). In Melbourne, Australia, proximity was not associated with walking to or within public open-spaces (Koohsari, Kaczynski, Giles-Corti, & Karakiewicz, 2013). Rather than proximity or geographic access, perceived park access—a multi-dimensional construct—appears to be a stronger predictor of park use in Brisbane and thus the range of benefits associated with urban parks (Wang et al., 2015).

4.3. Research design and validation

Participatory mapping methods can be effectively implemented across large urban areas as demonstrated in this study and other cities such as Helsinki (Kahila-Tani, Broberg, Kyttä, & Tyger, 2016). But given the human diversity and physical heterogeneity of urban areas, ensuring the representativeness of participants (both demographic and spatial) poses one of the greatest challenges to research validity when assessing public benefits from urban parks/reserves. Household surveys are experiencing higher refusal rates where nonresponse is more likely to induce bias in survey estimates (Groves, 2006). Our household response rate was low, but consistent with other participatory mapping studies (see Brown, 2017). In this study, random household, probability-based sampling was supplemented by a volunteer sample recruited through newsletters, social media, and participant referrals. These recruitment methods achieved acceptable spatial representation across the study area (Fig. 1), but probability-sampled participants were demographically biased toward older, more formally educated, and higher income individuals. These demographic results are consistent with findings of a previous survey of Brisbane park users which found park users to be somewhat older and with a higher level of formal education than non-park users (Lin et al., 2014). Our study participants also appeared to be more frequent users of parks than would otherwise be expected. About 78% of participants reported using parks at least once a week compared to about 60 percent found in a previous study (Lin et al., 2014). The participant bias toward more formal education, more familiarity with parks, and more frequent park use was greater in the volunteer sample than the household sample, an expected finding given the presumed greater saliency of parks issues to the volunteer group. A limitation of this study was the under-representation of Brisbane participants by lower socio-economic status or ethnicity, variables that can significantly influence park use and/or behavior (Dwyer & Gobster, 1992; Gobster, 2002; Shackleton & Blair, 2013). Further, our sampling methods did not directly target children, a key demographic for community health assessment. Participatory mapping methods can be implemented to identify children's behavior (Kyttä, Broberg, & Kahila, 2012) related to park use.

In participatory mapping with a typology of pre-defined attributes, the number of attributes to be mapped are necessarily constrained given the limited time participants are willing to engage in mapping activity. Our list of physical activities to be mapped included several new activities (dog walking, water-based activities, and supervising children in parks) not previously used, but as a web-design trade-off, the list of markers did not provide different MET intensity levels for walking, running, cycling, and sport activities as used in the Adelaide suburb study. In our analyses, we made assumptions about the MET intensity levels for all mapped activities (low, moderate, high) which are open to critique given participant variability in the actual physical intensity of these activities. Nonetheless, our findings regarding physical health benefits by park type based on assumed MET levels were consistent with previous research showing greater physical health benefits with larger urban parks in general, and linear parks in particular.

In the web-based mapping design, the placement of an activity marker was followed by two questions asking about how many times the activity was done in the past two weeks and the aggregate time spent doing the activity over the past two weeks. The purpose of these questions was to better estimate the physical health benefits associated with the mapped activities similar to research using activity-log methods. However, there were data quality issues with greater activity frequencies reported than the presumed maximum of 14 times over the two week period. We removed markers with inconsistencies in the frequency data and ran the analyses by weighting the markers by frequency under the assumption that the activity marker represented multiple visits. The net effect was to weaken the significant associations by park type, a likely result of introducing greater individual variability in park use that masked more fundamental activity/park associations.

The activity duration question asked for responses in hours over the two week period, but many responses appeared to be recorded in minutes. This question had the greatest potential to calibrate the MET data but the data were too inconsistent. In the future, the application would benefit from data error-checking logic to preclude participants from entering obvious out-of-range data. However, even if data quality were higher, large-scale participatory mapping across an urban park system does not appear to be the most appropriate method for achieving accurate physical health data on an individual person or park basis. If an important research objective is to achieve more accurate recording of park activities, physical activity logs or direct observation methods such as SOPARC could be used in combination with participatory mapping to calibrate the results.

5. Conclusion

In this study, we evaluated participatory mapping methods for assessing urban park benefits. The scaling-up of these methods from the suburb-level to a large urban-park system introduced greater variability in the results but multiple urban park benefits by park type associations were confirmed at the larger urban scale. Participatory mapping, with a focus on the distribution of park benefits in addition to physical design standards, can provide supplemental information to refine and adjust physical park standards.

There is contemporary academic interest in the assessment and analysis of urban areas for ecosystem services (e.g., Gómez-Baggethun & Barton, 2013; Rall et al., 2017; Woodruff & BenDor, 2016). The participatory mapping methods described in this study provide a means to assess cultural ecosystem services associated with urban parks and greenspaces. However, as noted by Ahearn et al. (2014), the assessment of urban ecosystem services alone does not provide the innovation required to inform routine urban and infrastructure development activity (Ahern, Cilliers, & Niemelä, 2014). And yet, participatory mapping offers the potential to better inform urban green infrastructure because of its spatially-explicit, systems approach to assessment focused on a range of benefits. Future research could analyze the spatial distribution of park benefits by suburb or neighborhood (spatial disaggregation) to identify social inequities in park benefits that could be addressed through further development of green infrastructure.

Acknowledgments

This research was funded by the Australian Research Council, ARC Discovery grant number DP130100218. This study was conducted with approval from the University of Queensland Human Research Ethics Committee (approval number: 2016001148). The research team expresses gratitude to the Brisbane City Council for their support in the project and to the residents of Brisbane who participated in the study.

References

ABS [Australian Bureau of Statistics] (2011). 2011 Census QuickStats. Available from: http://www.censusdata.abs.gov.au/census_services/getproduct/census/2011/quickstat/3GBRI?opendocument&navpos=220. Accessed 03.06.17.

ABS [Australian Bureau of Statistics]. 3218.0 – Regional Population Growth, Australia, 2014–15. (2015). Available from http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3218.02014-15?OpenDocument Accessed 03.06.17.

Ahern, J., Cilliers, S., & Niemelä, J. (2014). The concept of ecosystem services in adaptive urban planning and design: A framework for supporting innovation. *Landscape and Urban Planning, 125*, 254–259.

Bijker, R. A., & Sijtsma, F. J. (2017). A portfolio of natural places: Using a participatory GIS tool to compare the appreciation and use of green spaces inside and outside urban areas by urban residents. *Landscape and Urban Planning, 158*, 155–165.

Brown, G. (2017). A review of sampling effects and response bias in internet participatory mapping (PPGIS/PGIS/VGI). *Transactions in GIS, 21*, 39–56.

Brown, G. (2008). A theory of urban park geography. *Journal of Leisure Research, 40*, 589–607.

Brown, G., & Kyttä, M. (2014). Key issues and research priorities for public participation GIS (PPGIS): A synthesis based on empirical research. *Applied Geography, 46*, 122–136.

Brown, G., Schebella, M. F., & Weber, D. (2014). Using Participatory GIS to measure physical activity and urban park benefits. *Landscape and Urban Planning, 121*, 34–44.

Chiesura, A. (2004). The role of urban parks for the sustainable city. *Landscape and Urban Planning, 68*, 129–138.

Driver, B. L., Tinsley, H. E., & Manfredo, M. J. (1991). The paragraphs about leisure and recreation experience preference scales: Results from two inventories designed to assess the breadth of the perceived psychological benefits of leisure. In B. L. Driver, P. J. Brown, & G. L. Peterson (Eds.). *Benefits of leisure* (pp. 263–286). State College, PA: Venture Publishing.

Dwyer, J. F., & Gobster, P. H. (1992). Black/white outdoor recreation preferences and participation: Illinois State Parks. In: Vander Stoep, Gail A., ed. 1992. Proceedings of the 1991 Northeastern Recreation Research Symposium; 1991 April 7–9; Saratoga Springs, NY. Gen. Tech. Rep. NE-160. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 20–24.

Gobster, P. H. (2002). Managing urban parks for racially and ethnically diverse clientele. *Leisure Sciences, 24*, 143–159.

Gómez-Baggethun, E., & Barton, D. N. (2013). Classifying and valuing ecosystem services for urban planning. *Ecological Economics, 86*, 235–245.

Groves, R. M. (2006). Nonresponse rates and nonresponse bias in household surveys. *Public Opinion Quarterly, 70*(5), 646–675.

Ibes, D. C. (2015). A multi-dimensional classification and equity analysis of an urban park system: A novel methodology and case study application. *Landscape and Urban Planning, 137*, 122–137.

Ives, C. D., Oke, C., Hehir, A., Gordon, A., Wang, Y., & Bekessy, S. A. (2017). Capturing residents' values for urban green space: Mapping, analysis and guidance for practice. *Landscape and Urban Planning, 161*, 32–43.

Jennings, V., Larson, L., & Yun, J. (2016). Advancing sustainability through urban green space: Cultural ecosystem services, equity, and social determinants of health. *International Journal of Environmental Research and Public Health, 13*(2), 196.

Jette, M., Sidney, K., & Blümchen, G. (1990). Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. *Clinical Cardiology, 13*(8), 555–565.

Kaczynski, A. T., Besenyi, G. M., Stanis, S. A. W., Koohsari, M. J., Oestman, K. B., Bergstrom, R., ... Reis, R. S., et al. (2014). Are park proximity and park features related to park use and park-based physical activity among adults? Variations by multiple socio-demographic characteristics. *International Journal of Behavioral Nutrition and Physical Activity, 11*(1), 146.

Kahila-Tani, M., Broberg, A., Kyttä, M., & Tyger, T. (2016). Let the citizens map—public participation GIS as a planning support system in the Helsinki Master Plan Process. *Planning Practice & Research, 31*(2), 195–214.

Karimi, A., Brown, G., & Hockings, M. (2015). Methods and participatory approaches for identifying social-ecological hotspots. *Applied Geography, 63*, 9–20.

Kimpton, A. (2017). A spatial analytic approach for classifying greenspace and comparing greenspace social equity. *Applied Geography, 82*, 129–142.

Koohsari, M. J., Kaczynski, A. T., Giles-Corti, B., & Karakiewicz, J. A. (2013). Effects of access to public open spaces on walking: Is proximity enough? *Landscape and Urban Planning, 117*, 92–99.

Kyttä, M., Broberg, A., & Kahila, M. (2012). Urban environment and children's active lifestyle: SoftGIS revealing children's behavioral patterns and meaningful places. *American Journal of Health Promotion, 26*(5), 137–148.

Larson, L. R., Jennings, V., & Cloutier, S. A. (2016). Public parks and wellbeing in urban areas of the United States. *PLoS ONE, 11*(4), e0153211.

Lee, A. C., & Maheswaran, R. (2011). The health benefits of urban green spaces: A review of the evidence. *Journal of Public Health, 33*(2), 212–222.

Lin, B. B., Fuller, R. A., Bush, R., Gaston, K. J., & Shanahan, D. F. (2014). Opportunity or orientation? Who uses urban parks and why. *PLoS ONE, 9*(1), e87422.

McKenzie, T. L. (2005). *Systematic observation: SOPLAY/SOPARC introduction, practice, and assessment.* San Diego, California: San Diego State University.

Mertes, J. D., & Hall, J. R. (1996). *Park, recreation, open space and greenway guidelines.* USA: National Recreation and Park Association.

Moore, R. L., & Driver, B. L. (2005). *Introduction to outdoor recreation: Providing and managing natural resource based opportunities.* State College, PA: Venture Publishing, Inc.

Pietrzyk-Kaszyńska, A., Czepkiewicz, M., & Kronenberg, J. (2017). Eliciting non-monetary values of formal and informal urban green spaces using public participation GIS. *Landscape and Urban Planning, 160*, 85–95.

Pocewicz, A., Nielsen-Pincus, M., Brown, G., & Schnitzer, R. (2012). An evaluation of internet versus paper-based methods for Public Participation Geographic Information Systems (PPGIS). *Transactions in GIS, 16*, 39–53.

Rall, E., Bieling, C., Zytynska, S., & Haase, D. (2017). Exploring city-wide patterns of cultural ecosystem service perceptions and use. *Ecological Indicators, 77*, 80–95.

Ribeiro, F. P., & Ribeiro, K. T. (2016). Participative mapping of cultural ecosystem services in Pedra Branca State Park, Brazil. *Natureza & Conservação, 14*(2), 120–127.

Shackleton, C. M., & Blair, A. (2013). Perceptions and use of public green space is influenced by it relative abundance in two small towns in South Africa. *Landscape and Urban Planning, 113*, 104–112.

Shannon, C. E. (1948). A mathematical theory of communication. *The Bell System Technical Journal, 27* 379–423 and 623–656.

Schipperijn, J., Ekholm, O., Stigsdotter, U. K., Toftager, M., Bentsen, P., Kamper-Jørgensen, F., et al. (2010). Factors influencing the use of green space: Results from a Danish national representative survey. *Landscape and Urban Planning, 95*(3), 130–137.

Tyrväinen, L., Mäkinen, K., & Schipperijn, J. (2007). Tools for mapping social values of urban woodlands and other green areas. *Landscape and Urban Planning, 79*(1), 5–19.

United Nations (2015). *World Urbanization Prospects: The 2014 Revision (ST/ESA/SER.A/366).* Department of Economic and Social Affairs, Population Division.

Wang, D., Brown, G., Liu, Y., & Mateo-Babiano, I. (2015). A comparison of perceived and geographic access to predict urban park use. *Cities, 42*, 85–96.

Wang, D., Brown, G., & Liu, Y. (2015). The physical and non-physical factors that influence perceived access to urban parks. *Landscape and Urban Planning, 133*, 53–66.

Woodruff, S. C., & BenDor, T. K. (2016). Ecosystem services in urban planning: Comparative paradigms and guidelines for high quality plans. *Landscape and Urban Planning, 152*, 90–100.