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Exploring park crowding across a metropolitan region using a GIS-based observational methodology: The case of six Greater Montreal parks

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Abstract
Understanding how park configurations and equipment impact the ways people use parks can help create more appropriate park design in function of users' needs. Research on parks in Canada tends to ignore how to empirically evaluate park crowding. In this paper, we put forward a GIS-based observational method to examine the notion of crowding in different types of parks. This methodological approach is applied to six Greater Montreal parks located in urban core and suburban neighborhoods that have different levels of accessibility. Our bivariate and visual analyses point to some determinants of park crowding, i.e., accessibility indicators (proximity and hectares per person), urban services near the parks (e.g., daycares), and park equipment. We show sports facilities attract all visitors, but a low presence of adolescents and seniors is observed in all parks. Urban core parks offer less passive activity infrastructure but have more diverse uses and crowding than suburban parks.

Keywords: park design; park planning; suburban parks; urban parks, systematic observation

Résumé
Comprendre comment la configuration et l'équipement des parcs influencent les utilisateurs peut aider à créer des parcs mieux adaptés à leurs besoins. La recherche sur les parcs au Canada tend à ignorer la façon d'évaluer empiriquement l'achandalage dans les parcs. Dans cet article, nous proposons une méthode d'observation basée sur le SIG pour examiner la notion d'achandalage dans différents types de parcs. Cette approche méthodologique est appliquée à six parcs du Grand Montréal localisés dans des quartiers centraux et suburbains ayant différents niveaux d'accessibilité. Nos analyses bivariées et visuelles mettent en évidence certains déterminants de l'achandalage dans les parcs, à savoir les indicateurs d'accessibilité (hectares par personne), les services urbains à proximité des parcs (par exemple, les garderies) et les équipements dans les parcs. Nous montrons que les installations sportives attirent tous les visiteurs, mais qu'une faible présence d'adolescents et de personnes âgées est observée dans tous les parcs. Les parcs des quartiers centraux offrent moins d'infrastructures d'activités passives, mais ils ont des usages plus diversifiés et une achalandage plus importante que les parcs de banlieue.

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Mots-clés : aménagement des parcs ; planification des parcs ; parcs banlieue ; parcs urbains, observation systématique

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Introduction

Parks are considered important urban infrastructure that improve human wellbeing and urban sustainability (Das et al. 2022). Furthermore, the social, physical, and mental benefits of neighborhood parks are well known and documented today. Parks can be a place for social connection and gatherings (Chiesura 2004; Moore et al. 2010; van Aalst and Brands 2020), for practicing physical and recreational activities (A. Lee and Maheswaran 2011; Cohen et al. 2010), and can also provide mental respite (Nordh, Alalouch, and Hartig 2011; Peschardt, Schipperijn, and Stigsdotter 2012).

Such benefits can only be guaranteed if people visit and use parks, which in turn depends on specific park characteristics (Byrne and Wolch 2009; Byrne 2012; Wang et al. 2015). More specifically, studies have shown accessibility, facilities, maintenance, and equipment diversity increase park use among various age groups (Rung et al. 2011; Maroko et al. 2009; McCormack et al. 2010). As an element of park planning, accessibility has been studied in numerous ways, especially by the indicator of park proximity (Abercrombie et al. 2008; Gilliland et al. 2006; Smoyer-Tomic, Hewko, and Hodgson 2004; Talen 1997). Accessibility can be further understood by considering simultaneously park proximity (distance from residential areas to parks) and potential congestion (estimated by the population living nearby) (Maroko et al. 2009; Moore et al. 2010; Hughey et al. 2016; Jepson, Apparicio, and Pham 2022).

Yet, to our knowledge, there is a shortage of studies estimating crowding in parks and how crowding is impacted by accessibility levels. We identify three gaps in our knowledge of park design, the relationship between crowding and park facilities, and how to measure crowding. First, previous studies have explored park design in terms of size and facilities (e.g., number, type, and quality) and showed the number and type of facilities can increase park use (Li and Yang 2021; Coen and Ross 2006; Kaczynski, Potwarka, and Saelens 2008; McCormack et al. 2010; Rigolon, Browning, and Jennings 2018). Nonetheless, very few focus on how these design details impact park use, when being coupled with characteristics of the surrounding neighborhood. Factors such as the urban form of the neighborhood in which a park is located, the number of potential users in the park's surrounding area, and the park's facilities are intricately woven into park planning and design; however, these factors are not always considered. Therefore, while park planning plays a huge role in these decisions, the actual design of the park can also be made to ensure parks respond to the needs of those living close by to provide the facilities preferred by nearby residents, thus increasing use (Mehta and Mahato 2020; Powers et al. 2022).

Second, many European and US studies have focused on the relationships between park configuration and usage patterns (Ostermann 2010; Mehta and Mahato 2020; Marušić 2011; Goličnik and Ward Thompson 2010; van Aalst and Brands 2020). However, there has not been a lot of research on the relationship between crowding and facilities. Furthermore, neighborhood parks have not been compared in different urban contexts. Indeed, previous park accessibility and use studies were conducted in mid-sized cities and the urban core of metropolitan areas. In Canada, we can point to research in London, Ontario (Gilliland et al. 2006), Edmonton (Smoyer-Tomic, Hewko, and Hodgson 2004), and the City of Montreal (Reyes, Páez, and Morency 2014; Coen and Ross 2006; Moore et al. 2010). They find low spatial inequities in these areas, yet they find parks with inadequate facilities throughout these regions, which remained out of their research scope for these specific studies.

This leads to the third gap, considering how studies compute crowding. Studies of park accessibility are abundant, primarily using GIS-based computations of spatial accessibility to parks and various spatial data sources such as street networks, park location, and census data (Smoyer-Tomic, Hewko, and Hodgson 2004; Gilliland et al. 2006; Dai 2011; Ngom, Gosselin, and Blais 2016; De Alvarenga, Apparicio, and Séguin 2018; Cohen et al. 2010; Sister, Wolch, and Wilson 2010). Yet, estimations on potential crowding are done by computing the park surface (and their equipment) per capita. This indicator of potential park crowding is not validated with observational data, even though crowding is a significant factor influencing park use for both adolescents (Rivera et al. 2022) and seniors (Arnberger et al. 2017). It is important to understand that crowding can have positive and negative effects (van Aalst and Brands

2020; Van Hecke et al. 2016; Rivera et al. 2022; Cohen et al. 2010; Rung et al. 2011). Therefore, analyzing peak hours of use or equipment in a park helps identify popular areas and gain a deeper understanding of the intricacies of the concept.

To start bridging the above gaps, we put forward a methodology in this study to examine park crowding in different types of parks (having different levels of accessibility and design). We characterized park crowding by measuring park visitors' presence and their activities, both temporally and spatially, within the park perimeters. To put it differently, we looked at the number of visitors throughout time and the park space. Although we did not set a threshold to evaluate crowdedness, we consider the spatial patterns of users represented by crowding. We also paid attention to park layout and its role in determining crowding. As a result, this study aims to further develop observational methods and spatial analyses for park crowding. To demonstrate, six parks in the Greater Montreal area, including three in suburbs and three in urban core neighborhoods, were selected to examine park settings, equipment, and crowding. We collected data through systematic observations and analyzed crowding in function of different activity types, days and times of the day, ages, and group size, while considering park location and layout. To examine crowding variations across the parks, each of these categories of users and their activities was represented in three different ways. We hope to inform urban researchers of a methodology capable of empirically measuring crowding and provide a nuanced understanding of its temporal and spatial variation within parks.

Literature review

Park planning and design in North America

Park design (park size, facilities, and layout) is an important determinant of park (non)use as it can impact individuals' use of space and experiences of parks. It can also influence how users coexist within the space or if conflict arises. For example, Loukaitou-Sideris (1995), in Los Angeles, highlights designing sports fields too close to playgrounds may entice tensions between parents and teens or the lack of certain facilities that lead to the use of other equipment in other ways than intended. Moreover, park design is essential in determining how different nearby groups' needs in terms of park infrastructure can be supported. Mehta and Mahato (2020) find that parks in Cincinnati (Ohio) lack inclusion (accessibility) and diversity (ability to support multiple uses at varying times of the week), especially when considering users who might come from the surrounding neighborhood. Without conforming to a one-size-fits-all park model, they highlight specific park facilities that can accommodate diverse uses, such as different kinds of seating, informal areas, swings, spaces dedicated to children, and water play areas (Mehta and Mahato 2020).

Yet, studies on historical park design show the standardization of design in North American cities, especially concerning the role of urban parks in urban life (Cranz 1982; Gold 1972; de Laplante 1990). More specifically, parks in Montreal around 1860 began as public spaces free of installations, and then, recreational facilities in parks increased between 1940 and 1970 (de Laplante 1990). American parks saw similar increases in recreational facilities during the 1930s, where physical activities took precedence over former views of leisure and rest (Cranz 1982; de Laplante 1990). As a result, parks became quasi-identical since the 1940s and accommodated solely physical activities (Cranz 1982; Loukaitou-Sideris 1995). Today, studies on park design, such as Loukaitou-Sideris (1995) and Mehta and Mahato (2020), have insisted on moving past and revisiting these recreational ideals that have carried through into park design. Research has, therefore, pushed against what Loukaitou-Sideris (1995) calls the standardization of park design. These studies argue for diverse and adaptable park spaces that respond to the needs of the nearby neighborhood, considering race and ethnicity, age, and income (Byrne 2012; Mehta and Mahato 2020; Low, Taplin, and Scheld 2005; Powers et al. 2022). It is necessary to change these recreational ideals by focusing on park design that is adapted to how parks are used today. This can be done by providing appropriate interventions into park design that effectively support visitors and branch away from standardization.

As such, park design should facilitate diverse uses and increase park use by considering sociodemographic profiles of visitors. For example, different park facilities will be attractive to different age groups and genders. Veitch et al. (2017), in Melbourne, Australia, associated equipment like slides and swings, as well as upkeep and maintenance, with positive park experiences for adolescents. Rivera et al. (2021) also find that female adolescent park users in Melbourne considered playgrounds as important park equipment, whereas male adolescents considered other park design factors, such as sports, size, and location. Similar studies have identified features, such as ponds, walking trails, and shade, that increase park use for adults and seniors (Arnberger et al. 2017; Veitch et al. 2022). In the next section, we will detail the relationship between park settings and park use patterns.

Spatial configurations and design factors influencing park use

Park usage patterns can be observed through behavioral mapping or observations (Park, Christensen, and Lee 2020; Ostermann 2010; Marušić 2011; Goličnik and Ward Thompson 2010; Mehta and Mahato 2020; Pérez del Pulgar, Anguelovski, and Connolly 2020; van Aalst and Brands 2020; H.-S. Lee, Shepley, and Huang 2009). These studies have investigated, for example, how children or teenagers respond to different playground settings and interactions within parks (Pérez del Pulgar, Anguelovski, and Connolly 2020; van Aalst and Brands 2020) or the density of users throughout time (Ostermann 2010; Park, Christensen, and Lee 2020). Through these processes, spatial occupancy patterns and their relation to park facilities or features can be unraveled. Spatial configurations change park use by promoting various kinds of activities, for example, organized sports, walking, or relaxing. In addition, Goličnik and Ward Thompson (2010), in Edinburgh and Ljubljana, find that both active and passive activities have buffer zones that occur between user groups. This means that park users naturally provided each other with different buffer zones depending on the activity type. Therefore, park configurations can allow for harmonious cohabitation in the park if space is allocated.

The surrounding environment is another factor that can impact park visits as it includes both park supply and spatial density, as well as accessibility. Lee (2019) argues that understanding the neighborhood context (especially land-use types such as residential, commercial, or institutional use) helps to design parks appropriately. Marušić (2011) finds if the park is located near a busy area, there is a possibility for more users. On the other hand, if the parks are closer to schools, more children may visit them after school. Sister et al. (2010) and Boone et al. (2009) highlight the need to consider population density around the park. A park located within a higher density neighborhood has more potential to be busy. Research has shown that the level of activity in a park can either deter or encourage park users, particularly adolescents. This can happen due to either having too many people around or the desire to be left alone (Rivera et al. 2022; Van Hecke et al. 2016). However, busy parks provide a sense of security and may be perceived as the popular place to be (van Aalst and Brands 2020). To accommodate both types of park users, it is essential to design the park's layout in such a way that both busy and quiet spaces can coexist. Also, it is widely recognized that an overuse of parks can result in an accelerated deterioration of its facilities (Cohen et al. 2020).

Park size is usually associated with more park users. In other words, the larger the park, the more facilities and services there are; hence, there are more users. Cohen et al. (2010) in southern California find that with every additional hectare, there was an increase in park users. However, larger parks tend to be in low-density areas, such as in the suburbs (Rigolon 2016), which may reduce the number of visitors, especially during weekdays.

Indeed, park crowding varies in function of time and day. Bertram et al. (2017) in Berlin and Li and Yang (2021) in Tucson, Arizona, find increased travel to larger parks during the weekend and the popularity of smaller neighborhood parks during the week. Park visits changes depend on the time of day as different activities and groups of users will be present at various hours. Park et al. (2020) find children and adolescents were the most numerous in parks on the weekday afternoons and seniors during weekend lunch. In terms of activities, passive activity is more prevalent during the weekend. Moreover, when observing gender, they did not observe drastic differences during the day. Furthermore, design features can impact park use across time periods, such as lighting during the evening, especially for female park users (Groshong et al. 2020; Cronan et al. 2008).

Based on this literature review, we examine park usage and crowding patterns (of different age groups, activities, and genders) in function of park configurations or layouts, equipment, and location (urban core versus suburbs). These analyses also take into account temporal and spatial changes of crowding. The methodology is detailed below.

Materials and methods

Study area and park selection

The Greater Montreal area consists of 82 municipalities governed by the Montreal Metropolitan Community (Communauté métropolitaine de Montréal, in French). Within the 4,374 km^2 of this metropolitan area, there are 3.8 million inhabitants and 3,915 parks (in 2016) (CMA 2019). We selected six parks based on a spatial analysis of dissemination areas[1] (DAs) in Greater Montreal using two accessibility measures: closest park (shortest walking distance) representing proximity to residential areas and facilities per inhabitants (gradient enhanced two-step floating catchment area) that represent park potential congestion. More specifically, the selection of the six neighborhood parks was based on four criteria: 1) three suburban parks and three urban core parks, 2) park size falling under neighborhood park classification (between 0.7 and 3.0 hectares), 3) park facilities (minimum of two facilities in-

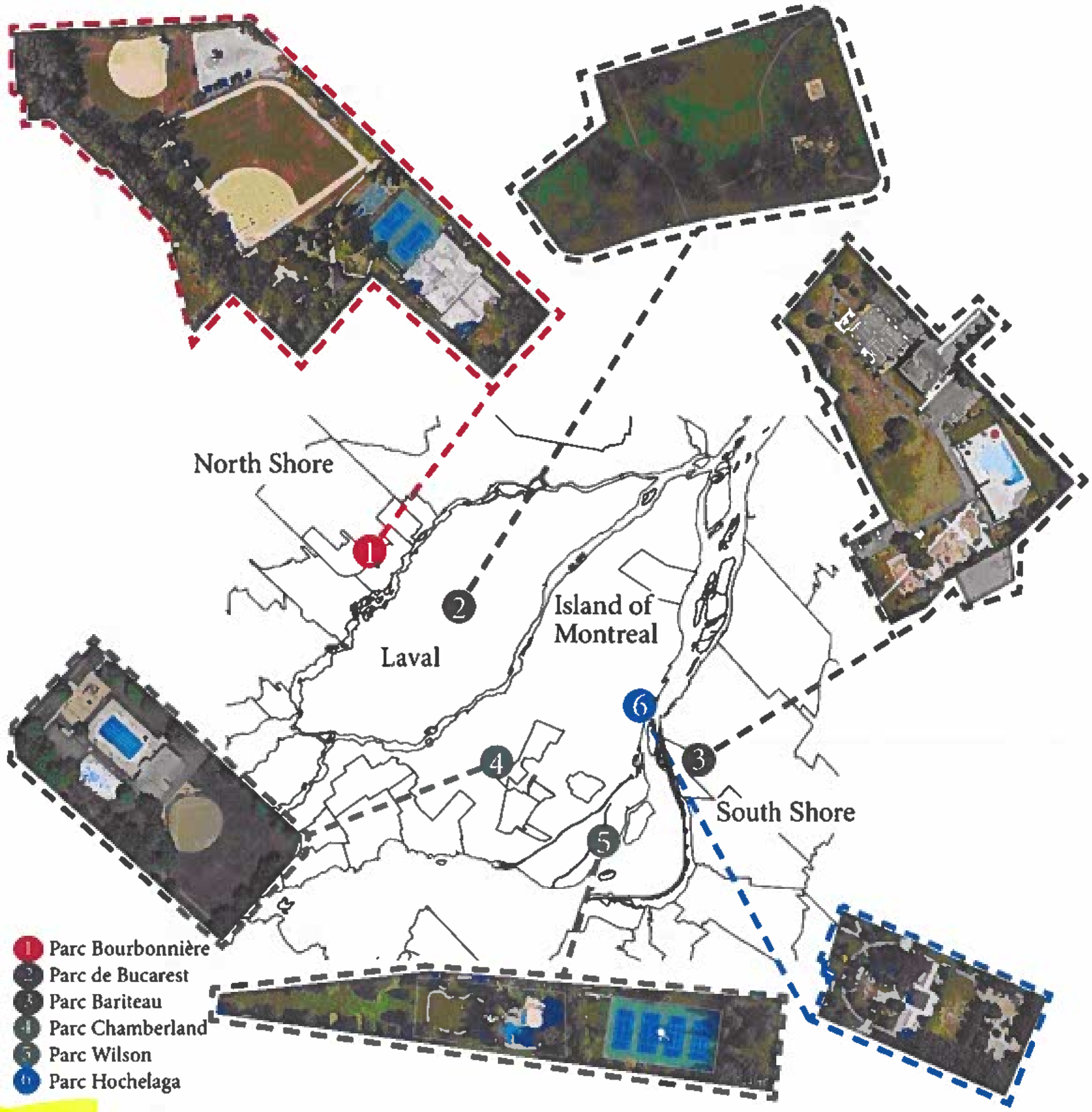

Figure 1
Location, configuration, and classification of the six selected parks in Greater Montreal

cluding a playground), 4) varying levels of park proximity and potential congestion (low level of proximity and low level of park congestion, low proximity and high congestion, high proximity and low congestion, high proximity and high congestion). The exclusion criteria included all parks with natural water features, bordering water or other parks, or containing large, forested areas. This was done to respect the park size and provide a park selection with similar perimeters. The location and configuration of these six selected parks are presented in Figure 1. The colors in the figure separate the parks' different accessibility combinations found in Table 1.

Table 1 presents the neighborhood context of each park, including park size, levels of proximity, and potential congestion, as well as percentages of different age groups within a 400m walking distance around the park (Jepson et al. 2022). The first selected park, Parc Bourbonnière, is located within a DA categorized by both low levels of park proximity and potential park congestion. The park is surrounded by single-family houses and a well-off,low-density neighborhood with lots of greenspaces. The following two parks, Parc de Bucarest and Parc Bariteau, were in DAs with low proximity and high potential congestion. Both are found in a typical suburban form, i.e., predominantly semi-detached houses, with Bariteau having several multiple-floor buildings and small businesses nearby. This suggests fewer users and low crowding in these parks. Two other parks, Parc Chamberland and Parc Wilson, are found in DAs categorized by high proximity and low potential congestion, located in the urban core (2-floor row houses, schools,

Table 1
Neighborhood context and park details

	Park Size	Accessibility[a]		Neighborhood context within a walking of 400 meters[b]					
Park	Hectare	Prox.	Cong.	Pop.	Inha/km[2b]	% 0-14[c]	% 15-24[c]	% 25-64[c]	% 65+[c]
Parc Bourbonnière	3.0	Low	Low	432	430	17.4	11.1	53.5	18.1
Parc de Bucarest	1.7	Low	High	1776	4230	15.4	12.7	56.9	14.9
Parc Bariteau	1.7	Low	High	2445	3634	9.5	9.0	53.2	28.3
Parc Chamberland	1.3	High	Low	1083	4533	18.8	14.4	48.1	18.7
Parc Wilson	1.7	High	Low	3779	10248	16.1	8.8	59.0	16.2
Parc Hochelaga	0.8	High	High	7893	14682	10.7	12.6	68.1	8.6

a) Proximity and potential congestion based on the typology proposed by Jepson, Apparicio, and Pham 2022 – removed for review. b) Census 2016 (Statistics Canada 2017). c) Age classifications based on Statistics Canada (2017): Children, Teens and young adults, Adults, and Seniors

and businesses), suggesting a higher number of users and more crowding. The last park, Parc Hochelaga, was selected from a DA categorized by high levels of park proximity and potential park congestion (surrounded by multiplexes, several public institutions, and businesses). This is a typical situation in old urban core neighborhoods, suggesting a very high level of crowding.

Finally, the different parks' facilities are mapped in Figure 2. In terms of sports facilities, there are baseball fields, basketball courts, a swimming pool and tennis/pickleball courts. Beyond sports, facilities include playgrounds, pétanque, and water play areas. Picnic tables and benches count as facilities but are not pictured in Figure 2. In most cases, the picnic areas are found near the playgrounds or sports facilities. Among the three parks in the urban core, Parc Chamberland's last major renovation was in 2010, when a new pool building was constructed, in addition to modern playground equipment. Parc Wilson, first inaugurated in 1951, recently reopened in 2017 after major renovations to the playground and tennis/pickleball courts. Parc Hochelaga, officially inaugurated as a park in 1930, had its last renovation in 2009. The three parks in the suburbs are newer. Parc Bourbonnière, one of Rosemère's three large parks inaugurated in 1974, had its first significant renovation in 1992 and provided sports field maintenance. Parc Bariteau, in 2015, inaugurated renovations, including a new pool and modern playground equipment. No date of creation has been found for Parc de Bucarest; however, its playground equipment is the most outdated. All six are typical neighborhood-level parks without any exceptional architectural style. By providing the aerial view and sketch maps of the six parks, we hope readers can grasp some understanding of their vegetation cover and facilities.

Data collection

Non-participative observations in the six parks were conducted over two weeks in June 2022. The swimming pool in Parc Chamberland opened during the week, but the only other pool in Parc Bariteau was not open. No special events took place. The observations were conducted during sunny days to represent the optimal park usage. Three observation periods were postponed because of rain but were rescheduled for the same time slot the following week. Observations were conducted every 30 minutes (for example, at 10:00 and 10:30 a.m.). We recorded the park users continuously and noted them during each interval. There was a morning observation period from 9h to 12h, an afternoon period from 12h to 15h, and an evening period from 15h to 18h. Blocks of observations were three hours long, and time slots differed during the week to capture a representative sampling of the whole week as follows: Monday (15h-18h), Tuesday (12h-15h), Wednesday (9h-12h), Friday (15h-18h), Saturday (9h-12h), and Sunday (12h-15h).

Initially, it was planned to accomplish 288 observation periods of 30 minutes, resulting in 144 hours of observations. However, consecutive Thursdays and Saturday afternoons of rain eliminated these time slots from the data collection, resulting in a total of 216 observation periods and 108 hours of observations.

Observations were recorded using the ArcGIS Survey123 on cell phones. The survey for the observations was predetermined by the first author before the data collection, and five student research assistants (graduate students in Urban Studies) attended training beforehand to ensure concurrency. Once in the park, each observer could see the entire park from their observation point. For each observation, we noted the geolocation (by positioning a point in ArcGIS Survey123) of users staying in the park for more than five minutes. Those walking, jogging, or biking through the park were noted if they spent more than five minutes doing such activity.

The research team members were encouraged to keep a fieldwork journal noting information related to the weather conditions, special events occurring in the park during the observations such as a sports tournament or

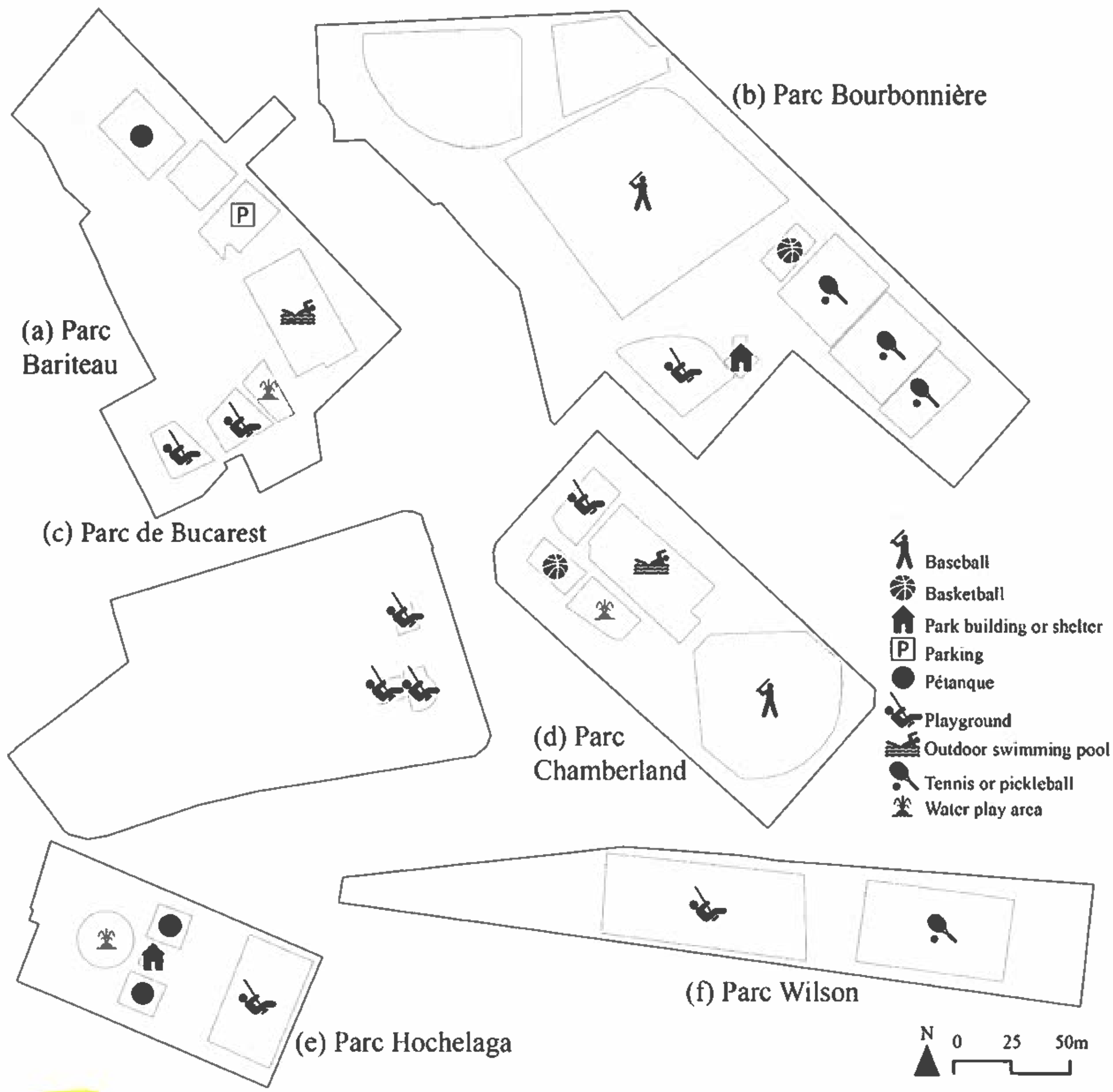

Figure 2
Facilities in the six parks

cultural activity, as well as the general appreciation of park crowding or park usage. As the observations were non-participative, the ages of park users were estimated (Table 5). The data was downloaded, cleaned, and organized on QGIS. The observation points were organized by park, time, and activity. At this point, the journals were also used to confirm unclear observations from the survey. The Research Ethics Board of the Institut national de la recherche approved the study protocol (project No. CER-22-656).

Statistical and visual analyses

Two types of analyses were conducted. First, bivariate analyses (contingency table and chi-square test of independence) were conducted to examine associations between the six parks and five variables representing park crowding, i.e., activity type, days of the week, time period, age group, and group size. These were calculated using R software (R Core Team 2021).

Second, we used point maps, proportional circles, and kernel densities to explore how the five variables of park crowding changed within each park, inspired by the work of Ostermann (2010), Mehta and Mahato (2020), Marušić (2011), and Goličnik and Ward Thompson (2010). For the point maps and proportional circles, it is important to keep in mind that one point represents an observation, whether an individual or groups of people visiting together. To calculate the kernel density estimations, we used a radius of 10 meters, a pixel size of 50 centimeters, a quadric kernel function, and a weighting for each observation. The weightings were based on the group size category as follows: 1 (single visitor), 2.5 (2 or 3 people), 4.5 (4 or 5 people), 8 (6 to 10 people), 15 (11 to 20 people), 25 (more than 20). This allows a more accurate visual of park crowding.

We also conducted correlation analyses between the five variables of crowding—activity type, days of the week, time period, and age group—to verify if their spatial patterns are similar or not. For example, a correlation between two kernel density maps of the weekday and the weekend can tell us if users occupied the same space of the park during the week and the weekend. For group sizes, we could not calculate kernel density estimations as it is the weighing for each variable; therefore, proportional circles are used to portray park use.

Results

Spatial dimension of park use and crowding

During the period of observation, 1588 observations, i.e., points of users, were collected in the six parks. Up to three activities could be recorded per single visitor or group, resulting in 1,282 observations with one activity (80.7%), 276 with two activities (17.4%), and 30 with three activities (1.89%), with a total of 1,924 activities. The most recorded activities were passive activity (41.8%), playgrounds (19.8%), and free play (10.4%) (Table 2). The chi-square test shows a significant association between the six parks and 12 activities ($\chi^2(55, N = 1924) = 1281, p < 0.001$).

Unsurprisingly, the three parks located in suburban areas (Bucarest, Bourbonnière, and Bariteau) have the lowest frequencies of park observations (64, 149, and 209), whereas three other parks in the City of Montréal (Chamberland, Wilson, Hochelaga) have the highest (553, 473, and 476).

Even though passive activity is the most observed activity overall (41.8%), it varies significantly according to the six parks. It is overrepresented in Hochelaga (67.6%), Bariteau (44.0%), de Bucarest (40.6%), and Chamberland (40.0%), and on the contrary, underrepresented in Wilson and Bourbonnière (28.5% and 6.0%). The same applies to playground use, which varies from less than 10% (Bourbonnière and de Bucarest) to 34.2% of visitors (Wilson). While all parks have playgrounds, Wilson has the highest percentage of playground use out of the six parks. In the two parks with tennis and/or pickleball courts, Bourbonnière and Wilson, these facilities are also well visited (45.0% and 17.5%, respectively).

Table 2
Contingency table between activity types and parks.

	Frequencies per park							Percentages per park						
	Suburban			Urban Core				Suburban			Urban Core			
Activity	BO	BU	BA	CH	WI	HO	All	BO	BU	BA	CH	WI	HO	All
Passive activity	9	26	92	221	135	322	805	6.0	40.6	44.0	40.0	28.5	67.6	41.8
Music	2	0	6	0	2	3	13	1.3	0.0	2.9	0.0	0.4	0.6	0.7
Walking a dog	2	10	3	0	4	6	25	1.3	15.6	1.4	0.0	0.8	1.3	1.3
Playground	13	6	50	69	162	81	381	8.7	9.4	23.9	12.5	34.2	17.0	19.8
Water play area	0	0	23	13	5	25	66	0.0	0.0	11.0	2.4	1.1	5.3	3.4
Free play	3	18	16	85	64	14	200	2.0	28.1	7.7	15.4	13.5	2.9	10.4
Exercise	1	3	7	58	10	7	86	0.7	4.7	3.3	10.5	2.1	1.5	4.5
Baseball	19	0	0	11	0	0	30	12.8	0.0	0.0	2.0	0.0	0.0	1.6
Basketball	13	0	3	54	0	0	70	8.7	0.0	1.4	9.8	0.0	0.0	3.6
Tennis or pickleball	67	0	0	0	83	0	150	45.0	0.0	0.0	0.0	17.5	0.0	7.8
Other sport games	1	0	3	3	4	8	19	0.7	0.0	1.4	0.5	0.8	1.7	1.0
Other	19	1	6	39	4	10	79	12.8	1.6	2.9	7.1	0.8	2.1	4.2
Total	149	64	209	553	473	476	1924							
%	7.7	3.3	10.9	28.7	24.6	24.7	100.0							

BA: parc Bariteau; BO: parc Bourbonnière; BU: parc de Bucarest; CH: parc Chamberland; HO: parc Hochelaga; WI : parc Wilson

Maps of activity types (Figure 3) reveal different spatial crowding patterns within each park. First, Hochelaga clearly has two distinct spatial patterns (Figure 3.e): a concentration of users in the playground area in the east part (light purple dots) and a large concentration of users in the rest of the park, of which the majority is passive activity. Second, the spatial patterns of users in Wilson and Chamberland show an overlapping of different activities throughout the parks (i.e., playground users, passive activities, and free play), with only a tiny part that is not frequently used, e.g., the baseball field of Chamberland and the open green space in Wilson (Figure 3.d and f). In summary, there is a much higher level of users for these three urban core parks during the period of observation. Recall that these parks are located in a DA characterized by a high level of park proximity (Table 1).

Inversely, the three other parks have rather dispersed spatial patterns, suggesting low usage and crowding. With this being said, the three suburban parks also show different spatial patterns. There is no activity overlapping in Bourbonnière; in other words, each part of the park is used for a specific activity (tennis, basketball, baseball, and the playground). Bariteau has little activity diversity: playground use and passive activity are mainly concentrated around the playground area. In Bucarest, only 64 observations are scattered and not even close to its three playground areas

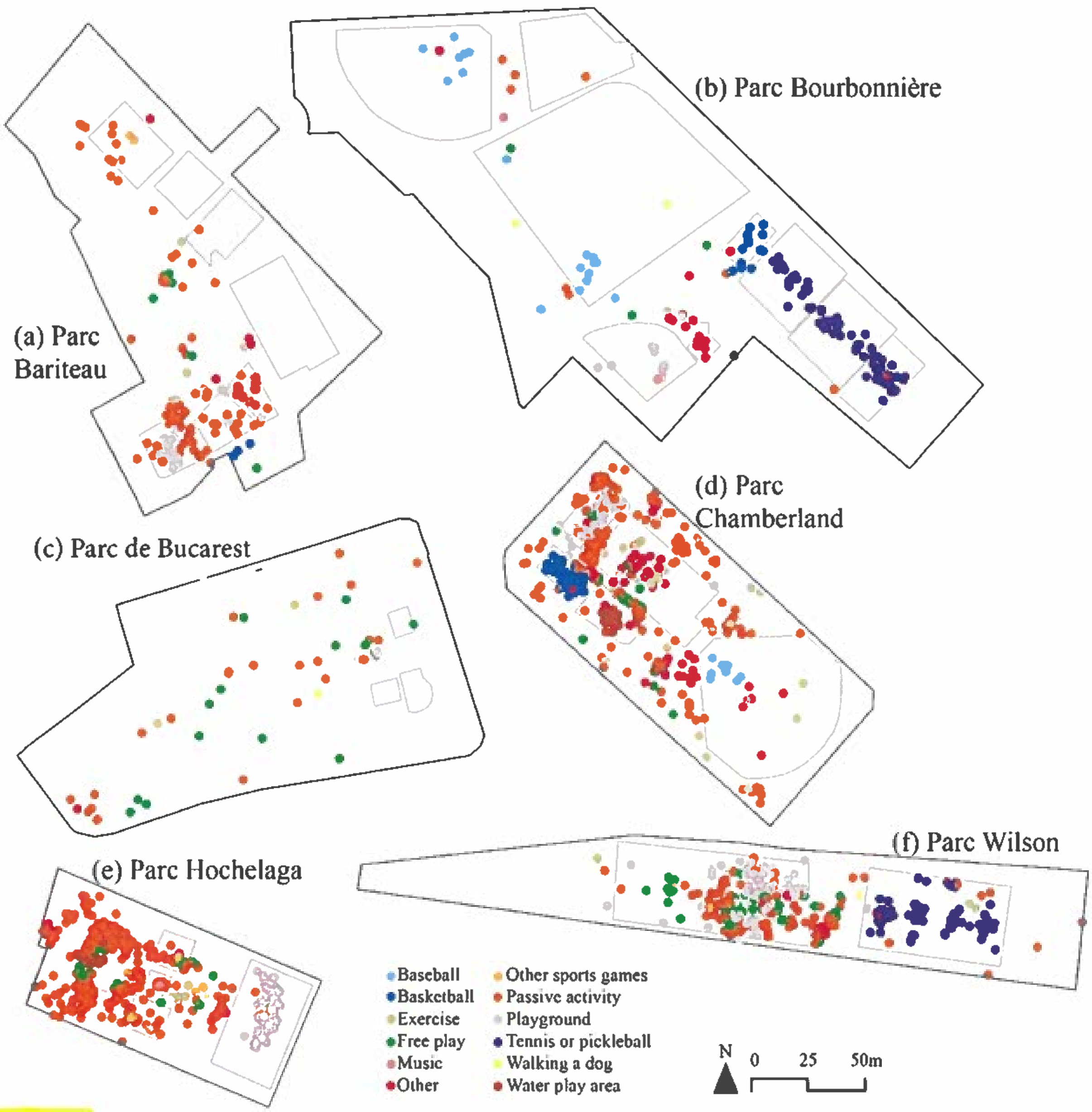

Figure 3
Activity types in the six parks

(Figure 3.d). For this reason, Bucarest is not retained for the other visual analyses. This finding confirms the typology of park proximity and congestion (Table 1) used to select the parks, i.e., the fact that people live far from a park and the low density of population around a park explains why the park is less used.

Due to the lack of space, for each crowding variable (activity type, day of week, period, age group, and group size), we only present the kernel density estimations of two parks to illustrate (dis)similarities in the park use spatial patterns. Note all the kernel maps are reported in the supplementary material.

Correlations of kernel density maps show that Hochelaga and Bourbonnière are the two parks that have the most dissimilarities between active and passive activity spatial patterns with r = 0.200 ($p < 0.001$) and r = −0.009 ($p = 0.074$), respectively. Such dissimilarities are explained by two different spatial patterns of usage within each park. Looking closely at the density of activities in each park (Figure 4), we note that in Bourbonnière, there is a higher density of active activity around the sports fields (e.g., tennis, baseball, and basketball), while passive activity occurs very minimally around the park. In Hochelaga, active activities are concentrated around the playground, while passive activities are spread out throughout the park area. Bariteau has a lower correlation than Bourbonnière because of parents accompanying children at the playground or water play areas, especially after the daycare lets out. As for the other urban core parks having lower correlations than Hochelaga, their similarities are due to the number and type of facilities found in the parks. Chamberland has a total of five different active activity facilities, and while Wilson

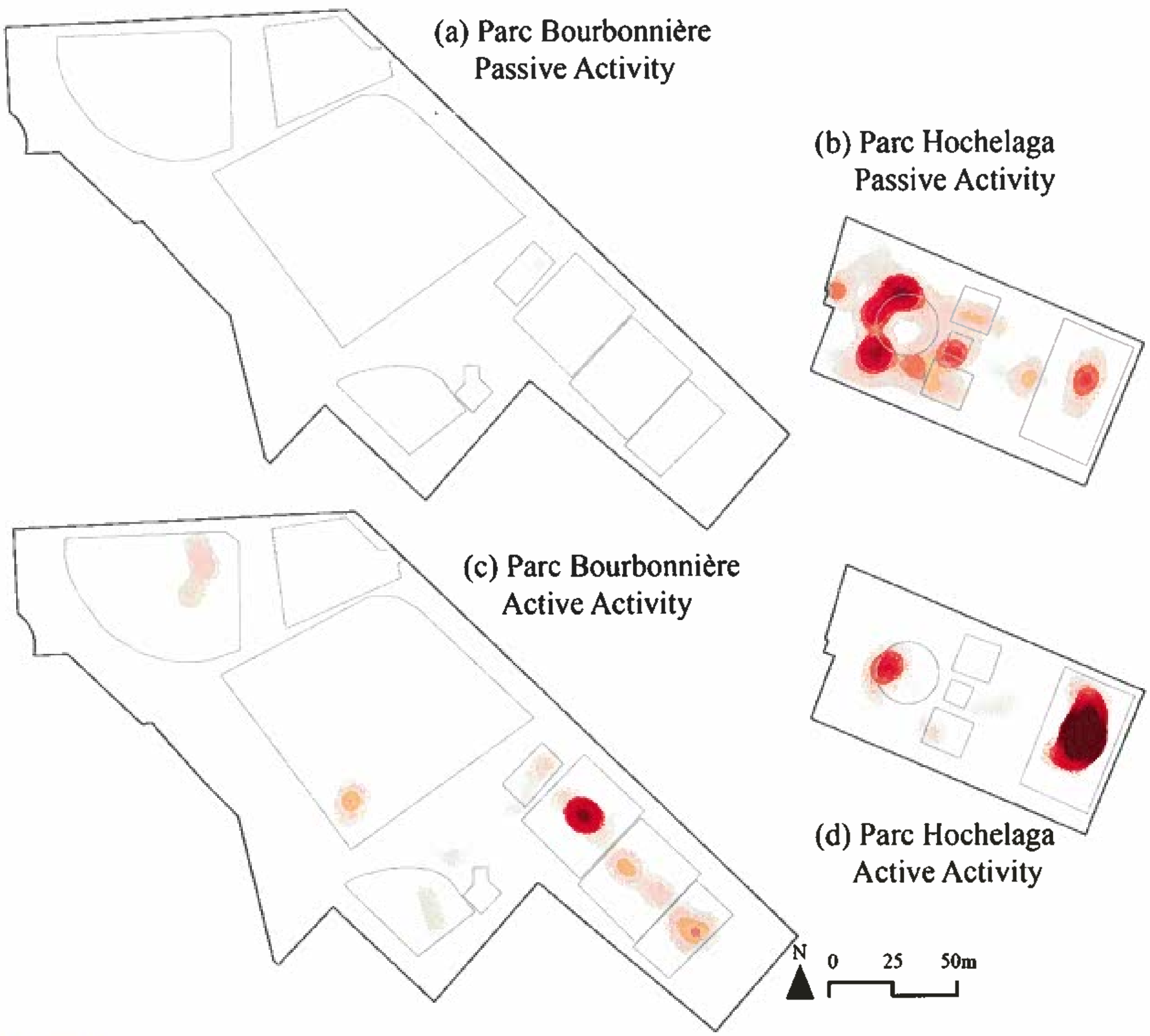

Figure 4
Density mapping for active and passive activities for Parc Bourbonnière and Hochelaga.

has only two, its playground contains diverse equipment appropriate for toddlers and young children, accompanied by swings and various seating arrangements often used by parents and for kids' birthdays. The diverse facilities within the parks increase the number of activities and result in a more extensive mix of uses.

Temporal dimension of park use and crowding

The chi-square test of independence reveals there are significant associations between the six parks and two temporal variables with $p < 0.001$: the day of the week with $\chi 2(5, N = 1588) = 37.6$ and the time period of the day (i.e., morning, afternoon and evening) with $\chi 2(10, N = 1588) = 47.1$. Table 3 shows that Bariteau is the park with the most difference in usage between weekdays and weekends (62.8% and 37.2%) (Table 3). This may be explained by the fact that although it is a suburban park, it is located next to a daycare, and, as a result, there is more use during the weekdays. In contrast, a typical suburban park located in a residential zone, such as Bucarest, has the most observed users during the weekend (68.8%). As for urban-core parks, their usage during the whole week varies slightly between 45% and 55% (Wilson and Hochelaga), with Chamberland having a higher usage on the weekend. For the suburban parks, weekday usage varies between 31.3% to 62.8% and 37.2% to 68.8% during the weekend, depicting quite different fluctuations in park use compared to the urban core parks.

Table 3

Contingency table between days of the week and parks

	Frequencies per park						Percentages per park						
	Suburban			Urban Core			Suburban			Urban Core			
Day of the week	BO	BU	BA	CH	WI	HO	BO	BU	BA	CH	WI	HO	**All**
Weekday[a]	60	15	86	178	169	244	41.1	31.3	62.8	41.0	45.0	54.6	**47.4**
Weekend[b]	86	33	51	256	207	203	58.9	68.8	37.2	59.0	55.1	45.4	**52.6**

a) Monday, Tuesday, and Wednesday. b) Friday evening, Saturday, and Sunday. BA: parc Bariteau; BO: parc Bourbonnière; BU: parc de Bucarest; CH: parc Chamberland; HO: parc Hochelaga; WI : parc Wilson.

The correlation coefficients between the kernel density of weekday and weekend show another picture in Bourbonnière and add new insight into our understanding of Chamberland as these two parks have the greatest dissimilarities of spatial patterns between weekdays and weekends ($r = 0.105$ and 0.454 with $p < 0.001$) (Figure 5). In Bourbonnière, the hotspot of weekday activity is found on the tennis courts, while a slightly larger density of users can be found around the baseball fields during the weekend. This demonstrates that in suburban parks, like in Bourbonnière, the sports fields seem to be used primarily on weekends.

In Chamberland, the density of users is higher during weekdays near the playground and on the basketball court, the density is higher during the weekend in the swimming pool, but the difference between weekday and weekend does not vary much. Otherwise, the correlations confirm the consistent whole-week usage in the other urban core parks, Hochelaga and Wilson, that we observe in the percentages of usage in Table 3 (their correlation coefficients being $r = 0.847$ and 0.723 with $p < 0.001$).

Concerning the time period, we find three main significant associations: the lowest percentage of afternoon visitors (35.4%) for Parc Wilson and the lowest and highest percentages of evening visitors for Parc Chamberland (21.0%) and Parc Bucarest (52.1%) (Table 4). This can be explained by the presence of families earlier in the morning and after the lunch hour in Wilson, leaving the park empty in the afternoon. While Bucarest has very few visitors throughout the day, denoting a very typical suburban park, which people visit after work. Bariteau's location close to a daycare explains the increase of evening users after the daycare closes.

For the density correlations by time period, the weaker correlation values are observed for the suburban Bourbonnière park. Inversely, spatial patterns of the three time periods are very similar for the Hochelaga, Bariteau, and Wilson parks (Figure 6), suggesting that these three parks were used in a consistent way (spatially speaking) throughout the day. This could be explained by Hochelaga and Wilson being located in dense neighborhoods where individuals go to parks often because they have less private space, and perhaps, the social fabrics in these neighborhoods are tighter (with people socializing more often). Bariteau's density of users by time period shows a pretty consistent use, however, the concentrated use of certain facilities, such as the playgrounds, can be explained by its proximity to the daycare.

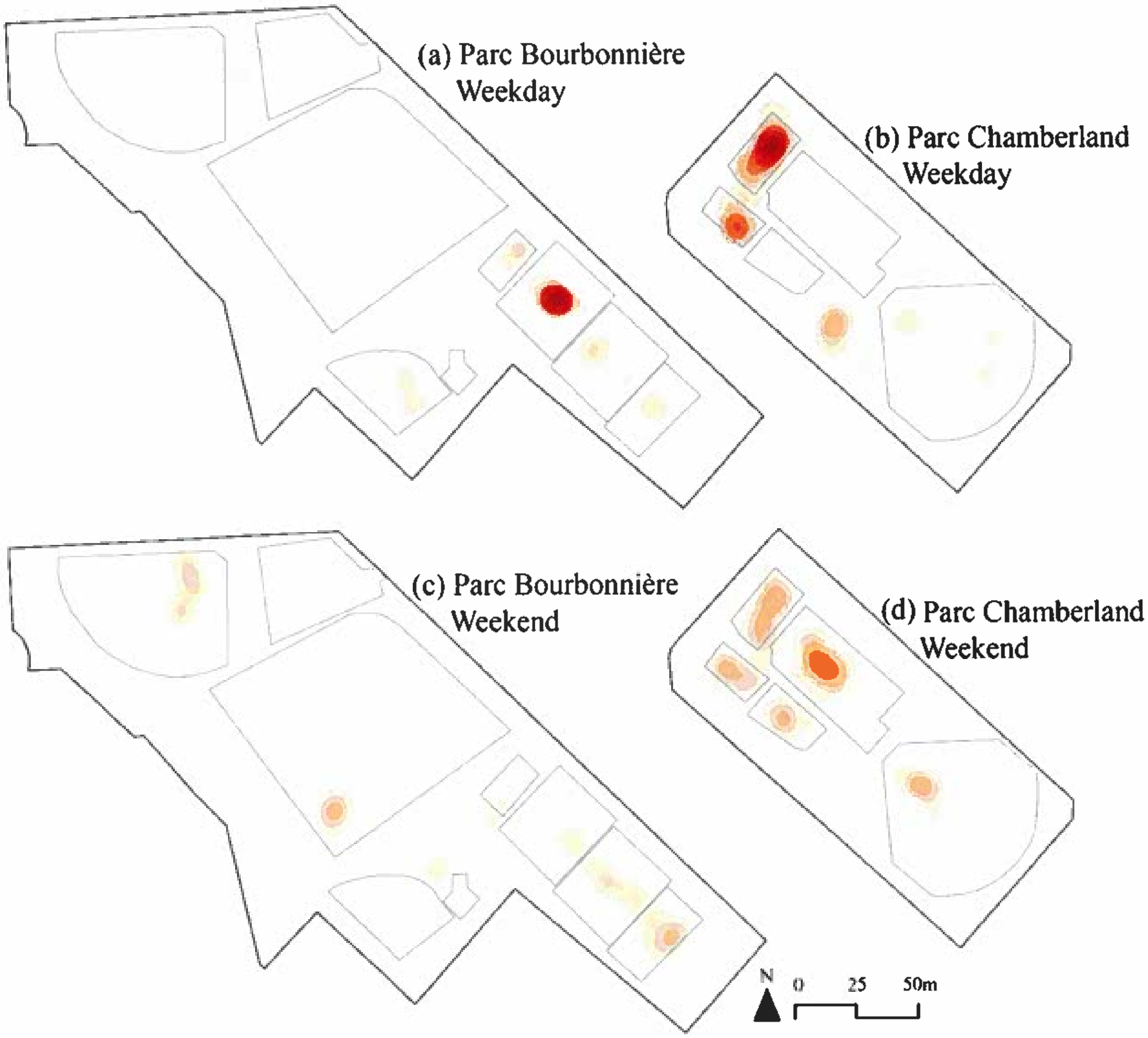

Figure 5
Density mapping for weekday and weekend visits for Parc Bourbonnière and Chamberland

Table 4
Contingency table between time period and parks

	Frequencies per park						Percentages per park						
	Suburban		Urban Core				Suburban		Urban Core				
Time Period	BO	BU	BA	CH	WI	HO	BO	BU	BA	CH	WI	HO	All
Morning[a]	38	6	36	132	114	102	26.0	12.5	26.3	30.4	30.3	23.8	**27.0**
Afternoon[b]	65	17	68	211	133	191	44.5	35.4	49.6	48.6	35.4	42.7	**43.1**
Evening[c]	43	25	33	91	129	154	29.5	52.1	24.1	21.0	34.3	34.5	**29.9**

a) Morning: 9h to 12h. b) Afternoon: 12h-15h. c) Evening: 15h to 18h. BA: parc Bariteau; BO: parc Bourbonnière; BU: parc de Bucarest; CH: parc Chamberland; HO: parc Hochelaga; WI : parc Wilson

Figure 6
Density of users by the time period in Parc Hochelaga, Bariteau, and Wilson

These temporal patterns within these parks demonstrate the differences of usages between suburban and urban core parks. The tendency is that suburban parks, like Bourbonnière and Bariteau, have specific uses, such as the playground (Bariteau) and the sports fields, mainly tennis courts (Bourbonnière). In the three urban core parks (Chamberland, Hochelaga, and Wilson), the whole park surface was used in an even way, and this was consistent across all periods of observation.

Park use according to age group and group size

The chi-square test of independence reveals there are significant associations between the six parks and age groups ($\chi 2(5, N = 1588) = 37.6, p < 0.001$), as well as group size ($\chi 2(20, N = 2032) = 198.8), p < 0.001$).

Concerning the demographic variable, teens and young adults, as well as seniors, were the least observed group for all parks (7.7% and 5.9%, Table 5), while children (0–14 years old) and adults (25–64 years old) are largest age groups of users (30.4% and 47.5%). Across the six parks, the variations of age groups do not seem to be associated with the fact that they are located in the suburban or in the urban core areas. For example, in the suburban parks, we observed the lowest but also the highest percentages of seniors (0.7% in Bourbonnière and 19.7% in Bariteau).

Table 5
Contingency table between age group and parks

	Frequencies per park						Percentages per park						
	Suburban			Urban Core			Suburban			Urban Core			
Age	BO	BU	BA	CH	WI	HO	BO	BU	BA	CH	WI	HO	All
Children[a]	37	21	66	178	210	106	25.3	43.8	48.2	41.0	55.9	23.7	30.4
Teens and young adults[b]	30	8	5	51	32	31	20.5	16.7	3.7	11.8	8.5	6.9	7.7
Adults[c]	96	22	81	203	212	351	65.8	45.8	59.1	46.8	56.4	78.5	47.5
Seniors[d]	1	6	27	18	42	25	0.7	12.5	19.7	4.1	11.2	5.6	5.9
Not Collected	19	2	18	67	42	25	13.0	4.2	13.1	15.4	11.2	5.6	8.5

a) 0-14 years. b) 15-24 years old. c) 25-64 years old. d) 65 and plus years old. BA: parc Bariteau; BO: parc Bourbonnière; BU: parc de Bucarest; CH: parc Chamberland; HO: parc Hochelaga; WI : parc Wilson

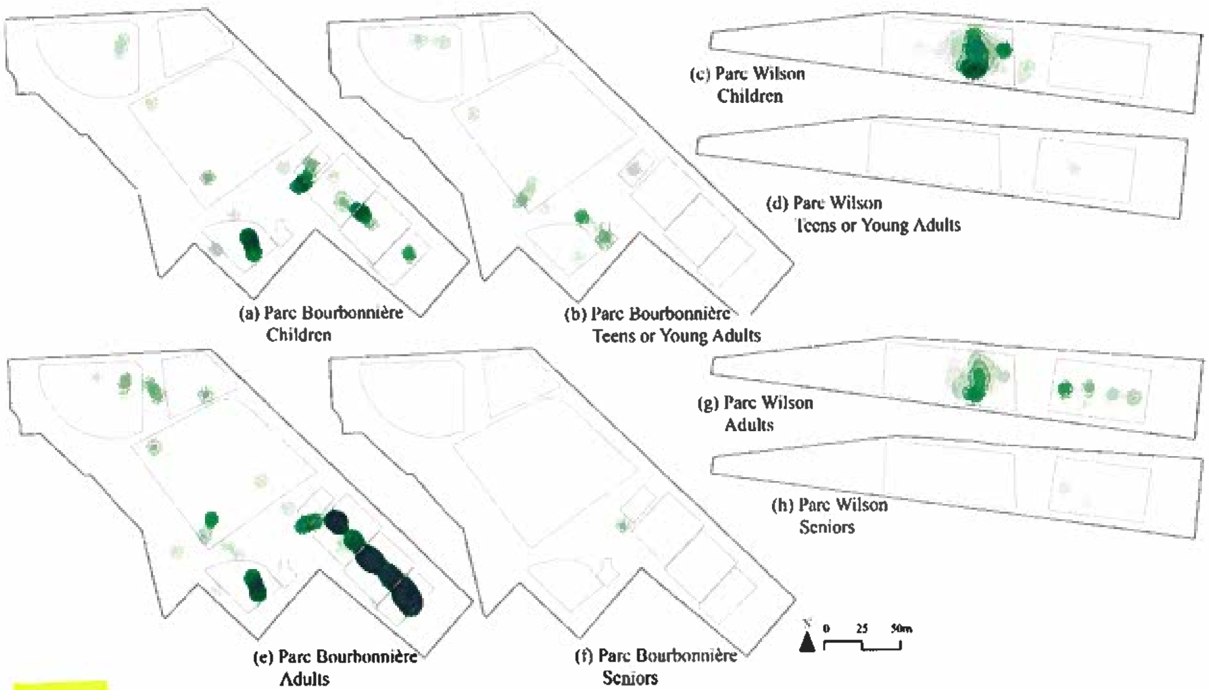

Figure 7
Density of users by age group of Bourbonnière and Wilson

Parc Bourbonnière has the largest dissimilarity when it comes to the kernel density correlations of age groups (weakest correlations in Figure 7). Children and their parents (adults) tend to be in the playground areas, while teens and young adults are near the sports fields. Again, this spatial clustering of users suggests the spatial separation of users due to the type of equipment found in the park that people choose to use according to their age. Inversely, spatial patterns of the four age groups are very similar for the Hochelaga, Chamberland, Bariteau, and Wilson parks (with a slightly higher concentration of children and their parents in the playground). The spatial patterns highlight again the lack of teens or young adults and senior visitors.

Concerning the group size, individual visitors and groups of 2–3 people were the most observed (29% and 49.1%) (Table 6). Larger groups with 6–10 people, 11–20 people, or more than 20, were much less observed in all parks (5.7%, 2.4%, and 1.8%, respectively). Some differences between the parks are worth mentioning. Larger groups were found in Chamberland (15.4% for 4–5 people and 3.7% for more than 20 people) due to summer camps and on the tennis courts in Bourbonnière (18.5% for 11–20 people). In Parc Hochelaga, individuals and smaller groups were omnipresent (46.8% and 42.3%), which may be due to the lack of sports fields. Groups of 2 or 3 are quite important in Parc Wilson (66.5%), often due to tennis court pairs or small families visiting the playground. The spatial maps (Figure 8) show more significant numbers of people in Chamberland, Hochelaga, and Wilson compared to Bariteau and Bourbonnière. The maps of individuals and groups in Figure 8 show that park use in various sizes is concentrated

Table 6
Contingency table between group size and parks

	Frequencies per park						Percentages per park						
Group Size	BO	BU	BA	CH	WI	HO	BO	BU	BA	CH	WI	HO	All
One person	32	18	33	134	35	209	21.9	37.5	24.1	30.9	9.3	46.8	29.0
2-3 people	75	24	75	166	250	189	51.4	50.0	54.7	38.2	66.5	42.3	49.1
4-5 people	20	5	11	67	49	24	13.7	10.4	8.0	15.4	13.0	5.4	11.1
6-10 people	9	1	11	32	30	7	10.0	2.1	8.0	7.4	8.0	1.6	5.7
11-20 people	10	6	7	19	10	8	18.5	0.0	5.1	4.4	2.7	1.8	3.4
More than 20	0	0	0	16	2	10	0.0	0.0	0.0	3.7	0.5	2.2	1.8

BA: parc Bariteau; BO: parc Bourbonnière; BU: parc de Bucarest; CH: parc Chamberland; HO: parc Hochelaga; WI : parc Wilson

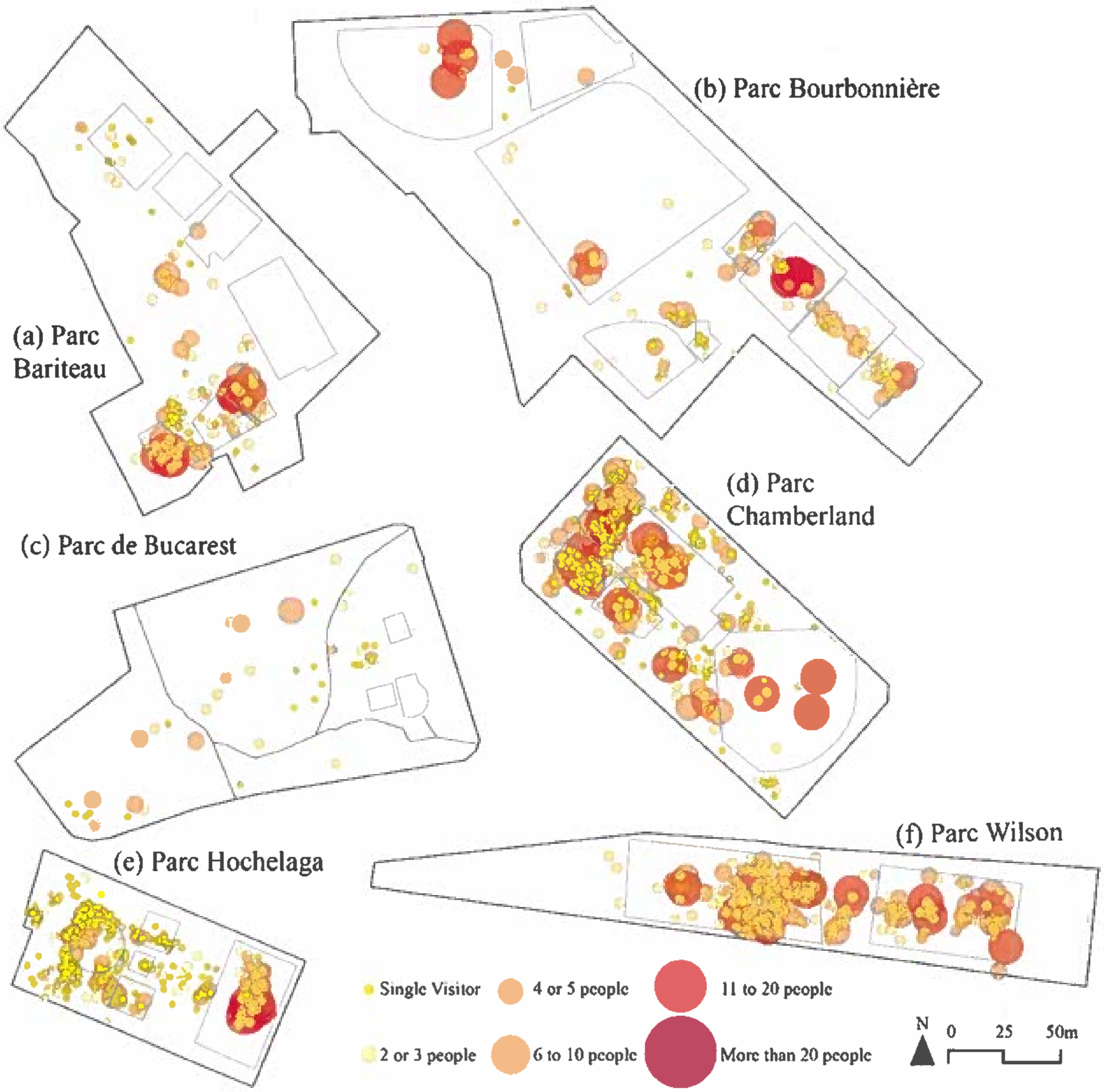

Figure 8
Park use by group size in each park

around the playgrounds in Bariteau and the sports facilities in Bourbonnière and Chamberland. The individual visitors can be seen in Parc Hochelaga in the area where picnic tables and benches are found, while a concentration of larger groups on the playground is present. Lastly, the mix of both groups of 2 or 3 and larger groups are found throughout Parc Wilson.

Discussion

In this study, observation data enables us to reveal fine spatial patterns of crowding within parks, for example, the separation of activities due to specific equipment (especially those allowing unique activities, such as sports or playgrounds). For example, in larger suburban parks with fewer users, activities are more spatially separated. Our observation data confirmed the typology of parks in function of their proximity and congestion that was computed based on secondary spatial data proposed by Jepson et al. (2022). More specifically, for three parks located in DAs with a high proximity to residential areas in the urban core, we find high levels of park use in terms of frequencies of observed users and groups (Tables 2 and 6). Furthermore, in Hochelaga, the park located in a DA with high proximity coupled with high congestion (because of the density of population surrounding the park), we find consistent use throughout the day and the week, as well as the highest levels of passive activity and individual visitors. In contrast, for the three parks located in DAs with a low level of proximity in the suburbs, we find very low park use and crowding despite their larger size compared to the urban core parks. Bariteau has a slightly higher frequency of users because of a daycare nearby, and these peak hours of use denote higher crowding at the playgrounds. Bourbonnière experiences high crowding at the tennis courts but low use everywhere else. We find that the surrounding area of the park matters as we saw an increase in park use to the daycare next to Bariteau.

To explain spatial patterns of crowding within the parks, three determinants are noted, i.e. park facilities, park's context and peoples' age. First, while facilities do not always improve levels of use due to factors such as condition and maintenance, we did find in this case that sports facilities are important aspects of parks that attract users. In parks like Bourbonnière, Chamberland, and Wilson, with different residential contexts, we can see consistent use of these facilities across the observation periods. This finding supports studies such as Cohen et al. (2010) and Gilliland et al. (2006), which underlined for the importance of park facilities for park use. However, contrary to studies like Kaczynski et al. (2007), we did not see an elevated park use with more facilities. We saw users visiting Bourbonnière solely for sports and physical activity, and diverse uses and a larger number of visitors in Chamberland having similar facilities. Chamberland is in a dissemination area that has the highest percentage of children ages 0–14 and 15–24 (Table 1). Wilson and Hochelaga experience large numbers of observations with few diverse equipment. To put it differently, the larger number of facilities in the park did not always attract a larger number of visitors. This may be a result of park location, given that Wilson, Hochelaga, and Chamberland are found in dense neighborhoods, while Bourbonnière is surrounded by homes with yards.

Second, we find in the urban core parks a more significant rate of passive activities (compared to active activities) and a spatially and temporally consistent usage of the full-park area. Among these three parks, the most notable one is Hochelaga, which is the park with the most passive activity not related to child supervision (e.g., larger presence of adults and individual park users). This could be due to the lack of private green spaces, such as backyards, in densely populated neighborhoods (Honey-Rosés et al. 2020; Rung et al. 2011). In suburban parks, crowding tended to be found when there were specific services or institutions nearby (such as daycare). We hence corroborate previous authors in that parks in lower-density areas, such as the parks in the suburbs, are less likely to experience crowding (Sister, Wolch, and Wilson 2010). This said, given the large rate of passive activity in our study parks, there is a need to provide park furniture for more passive use, such as seating areas in the shade, picnic tables, and swings.

Third, we highlight the lack of both teenagers or young adults and the senior age groups within our six parks. This finding is similar to other studies that noted that these age groups were less observed in parks (Mehta and Mahato 2020; Li and Yang 2021; Cutts et al. 2009). This is a prime example of updating the park design in order to support diverse uses. Research has shown that adolescent park users prefer certain infrastructure. For example, playgrounds have been shown to attract adolescent park users if they are not only geared toward young children (Veitch et al. 2017; Rivera et al. 2021; Van Hecke et al. 2018). While Wilson had diverse seating options, its playground was busy with young children and provided very little distance between users. Furthermore, given gender differences, such as female adolescents' lower park use and higher reported safety concerns, it is important to incorporate diverse features, such as swings and playgrounds that are attractive to diverse age groups and spaced out enough to minimize conflict (Rivera et al. 2021).

Furthermore, there is a controverse regarding teenagers' preferences towards crowding. Rivera et al. (2022) find that crowded parks discourage teen users in Melbourne, Australia. This could be for several reasons; for example, adolescents want a space where they do not bother nor are bothered by others (Van Hecke et al. 2016). However, other work showed that adolescents prefer highly visited parks either due to security or popularity (van Aalst and Brands 2020).

A question that arises from this study is 'What is the ideal crowing of a park?'. Two studies find that an 'ideal crowding' situation is important for increasing park use for all park users (Cohen et al. 2010) and seniors (Arnberger et al. 2017). Therefore, spatial configurations are determinant in park design in order to create enough space for all users and between users. However, given that the perception of crowding is such a personal experience and preference, future research can elaborate on the impact of crowding on park use.

Limitations to this study include the short timeframe. While it can be considered a snapshot of park use during the summer, a larger timeframe could indicate repeated patterns over a couple of weeks. This methodological process is flexible enough to be replicated in longer periods of time. In our study, we did not address either the race, ethnicity, or gender aspects, which would consist of important insights into further adapting park design to current needs. Historical records of park planning and construction could also be precious data to shed light on the causes underlying parks' quality and usage patterns.

Conclusion

The GIS-based observational approach presented in this study allows us to efficiently collect and analyze park use and crowding data. There are different reasons making us believe that the methodology can be used by municipal departments (e.g., urban planning, design, park and recreation, and social development) to assess park crowding. First, city professionals usually have access to mobile GIS solutions for field data collection (e.g., ArcGIS Survey 123, ArcGIS Field Map, QField). Second, bivariate analyses (contingency table and chi-square test of independence) and spatial analyses (kernel density estimation) are simple to calculate. Such data and tools can help planners and designers to update infrastructure that supports park users' and surrounding residents' needs to increase use by branching away from one-size-fits-all parks. This is especially important in urban core parks, given the elevated use and crowding we found. Specific attention to both adolescents and seniors would help increase park use for these age groups. In sum, incorporating data regarding park usage patterns and crowding within design today will create more equitable parks that improve the urban quality of life and update the role of parks in creating just and sustainable cities.

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Conflicts of Interest: The authors declare no conflict of interest. All authors have read and agreed to the published version of the manuscript.

End notes

[1]The DA unit is the smallest scale (usually 400 to 700 persons) on which sociodemographic data are disseminated by Statistics Canada (2017, 89).

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