sustainability

MDPI

Article

Using Big Data to Assess Park System Performance during the COVID-19 Pandemic

Shujuan Li [1], Bo Yang [1,*] and Haiquan Li [2]

1 School of Landscape Architecture and Planning, The University of Arizona, 1040 N. Olive Road, Tucson, AZ 85721, USA; shujuanli@arizona.edu
2 Department of Biosystems Engineering, College of Agriculture, Life and Environmental Sciences & College of Engineering, Statistics GIDP, Cancer Center, The University of Arizona, 1177 E 4th ST, Tucson, AZ 85721, USA; haiquan@arizona.edu
* Correspondence: boyang17@arizona.edu

Abstract: Parks provide essential services to urban dwellers, but the global COVID-19 pandemic significantly disrupted park usage. Despite this, little is known about the adaptation of visiting behaviors by the public and how visitation patterns vary across different types of parks. In this study, we utilized SafeGraph cellular human movement data to compare park visits in Tucson, Arizona (USA) before and during the pandemic (2019 vs. 2020). We reviewed park management measures in response to the pandemic alongside park visit data. Furthermore, we conducted a GIS analysis to compare the changes in park visits across different park types throughout various days and months. Results indicate that (1) fluctuations in park visits are strongly correlated with COVID-19-related measures; (2) different types of parks experience vastly different processes of visit decline and recovery; (3) river and linear parks maintain their appeal, likely due to the perception of reduced virus transmission risk associated with their primary activities, such as walking and bicycling; and (4) the contrast between weekend and weekday visit patterns reflects the extent of the pandemic impact. These findings offer valuable guidance for park management and park usage, attendance prediction, and design adaptations for future pandemics. We conclude that SafeGraph big data are effective for evaluating park system performance on a broader scale.

Keywords: Arizona; park management; park use; SafeGraph; Sonoran Desert; urban resilience

Citation: Li, S.; Yang, B.; Li, H. Using Big Data to Assess Park System Performance during the COVID-19 Pandemic. *Sustainability* **2023**, *15*, 16056. https://doi.org/10.3390/su152216056

Academic Editor: Francesco Caputo

Received: 14 October 2023
Revised: 11 November 2023
Accepted: 13 November 2023
Published: 17 November 2023

1. Introduction

A growing body of literature suggests that parks can provide recreational, social, and health benefits to communities and are imperative to urban dwellers [1–6]. However, the global coronavirus disease 2019 (COVID-19) pandemic had drastically compromised the accessibility and operational capacity of urban parks [7–9]. It greatly jeopardized physical activities and social interactions across countries [10–14]. There are various types of parks within a city's park system (e.g., metro, community, and neighborhood parks), and they provide different amenities and serve complementary functions [15]. However, it remains largely unknown how park users adapted their visiting behaviors in response to the park management measures implemented due to the COVID-19 pandemic. More specifically, it is unclear whether park users altered their behaviors in various types of parks within a city's park system.

In the US, parks remained open in most cities. However, in the early phase of the pandemic (i.e., March 2020), parks and recreation departments across the country adopted strict measures to curb virus spread, such as closing facilities, canceling recreation lessons and sports games, and limiting operating hours [16,17]. Many cities also imposed restrictions on the use of public transportation, which further limited park accessibility, especially for parks beyond walking distance [12]. To ensure that parks provide safe social spaces, the US Centers for Disease Control and Prevention (CDC) (2020) recommended that individuals and families should still visit local parks during the pandemic while maintaining physical distance from non-household persons [18]. The National Recreation and Park Association also encouraged safe park use during the pandemic, as evidenced by increased park visitations in different cities. Representative news media headlines included Google location data for Seattle that showed a decline in work, transit, and retail trips but not park visits [19], and mobility data showed a massive boost for Blount parks after the COVID-19 outbreak [20,21]. As the pandemic continued, cities were gradually transitioning from lockdowns to more flexible practices and reopening public spaces. It is expected that park users who wished to continue their leisure and exercise activities have adjusted their visiting behaviors in accordance with the pandemic situations and park usage regulations [19].

Research on park use, or green space use in general, is rapidly emerging in different countries during the pandemic [22–25]. Many studies have focused on the changes in visits to and use of parks, but mixed findings are reported [7,10,24,26]. Some studies reported a sharp decrease in park visits, while others found the opposite. Most studies examined urban green space that subsumes parks, but few specifically examined the impacts of COVID-19 on park visits. Furthermore, less is known about how visits to different types of parks change on a monthly (or even daily) basis, largely due to the lack of comprehensive datasets to perform the assessment. Previous studies also suggested that, before the pandemic, visits to various types of parks differed on weekdays and weekends [27,28]. People generally visit parks near their residences during weekdays, while preferring large parks over the weekend, being less concerned about the travel distance. However, it is unclear to what extent this visiting behavior (weekdays vs. weekends) remained true during the pandemic [7,18].

The study objectives are to (1) provide a chronological overview of park management measures at the city, state, and parks and recreation department levels and (2) compare park visits before and during the pandemic across different types of parks on weekdays and weekends. We examined the park system (139 parks) of Tucson, Arizona (USA).

2. Materials and Methods

2.1. Study Area

Tucson is located in Pima County, Arizona, close to the US-Mexico border and part of the Sonoran Desert (Figure 1). It has a population of 545,975, according to the 2020 American Community Survey. There are 183 parks within the City of Tucson's limits, including 155 parks managed by Tucson's Parks and Recreation Department (PRD) [29] and 28 by Pima County Nature and Park Resources. However, the desert environment that Tucson belongs to allows only a limited amount of greenery [30,31]. Urban parks, therefore, provide essential green spaces for social gatherings and outdoor recreational activities [28,29].

We chose Tucson because it epitomizes cities in the US Southwest region that experience rapid urban growth (e.g., the Arizona Sun Corridor, which encompasses five metropolitan areas). Quality parks and green spaces are needed to serve the growing population in this region. As one of the sunniest cities in the US (averaging 286 sunny days annually, with temperatures ranging from 6 °C to 39 °C), Tucson offers pleasant outdoor recreational activities almost year-round. Additionally, parks are a great asset to Tucsonans. Our previous studies show that despite the extreme heat in the summer, there were increased visits to some parks during the COVID-19 pandemic [28,32]. Lastly, Tucson shares similar challenges faced by other cities during the pandemic, including financial constraints and staff shortages to maintain park operations. Understanding the visitor behaviors at the park system level can contribute to sustainable park planning, design, and management post-pandemic.

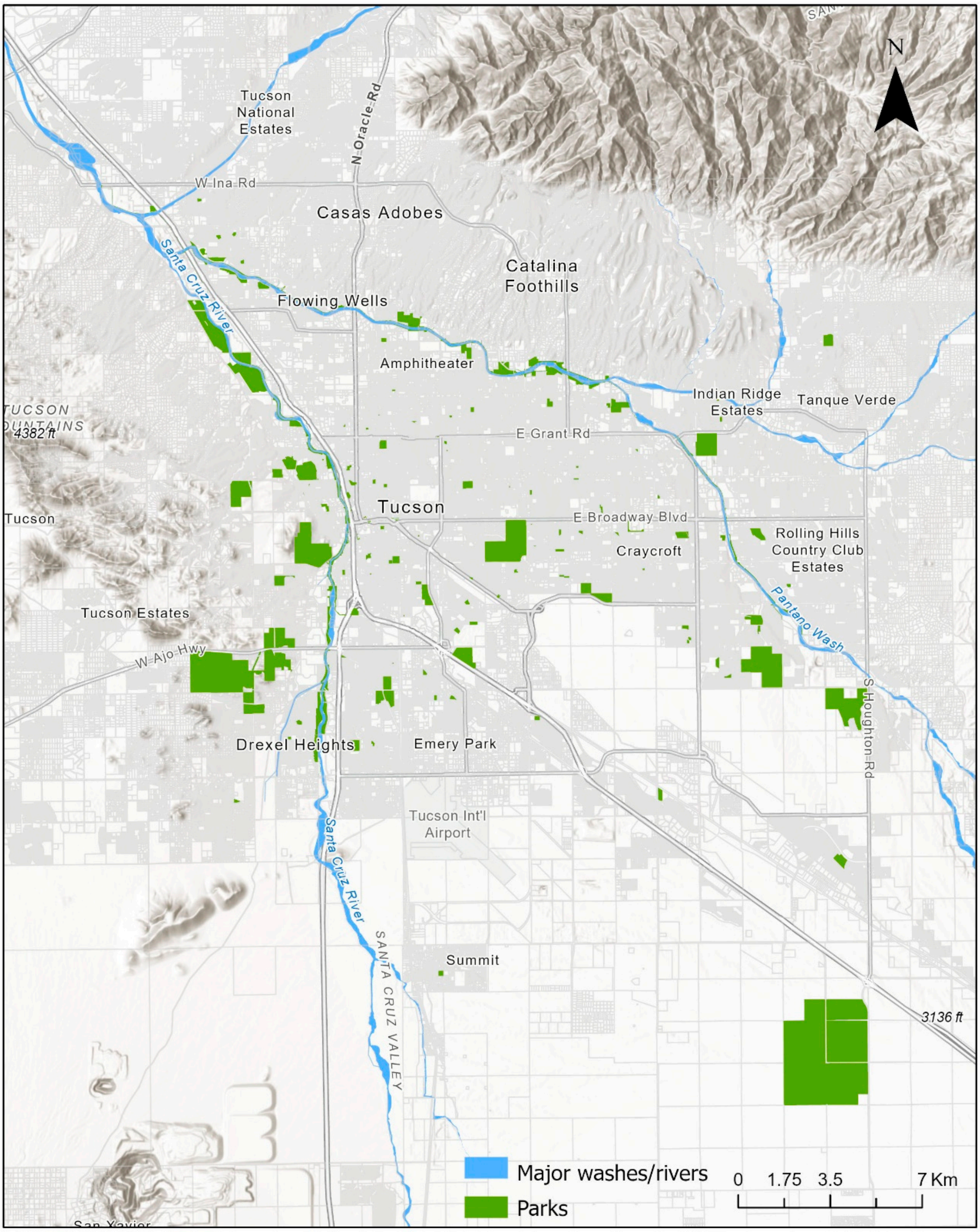

Figure 1. Parks in Tucson, Arizona (USA).

2.2. Data

Park management information was collected from the Tucson Parks and Recreation Department's website, social media webpages (Facebook and Twitter), and City of Tucson news media for the Year 2020. GIS data of park boundaries were downloaded from the Pima County GIS Server. Park visit data were retrieved from SafeGraph (https://www.Safegraph.com/, accessed on 15 June 2021). SafeGraph provides datasets with aggregated and anonymous human movement information from 45 million smartphone devices [7,33] and captures the mobility patterns of over 10% of the entire population in the US [7,34]. Data on daily and monthly visits to parks in 2019 and 2020 were extracted for this study, following the procedure described in other studies that used the SafeGraph dataset [26,33,35,36].

In the SafeGraph dataset, aggregated human movement information is organized and provided for places defined as points of interest (POIs) [37]. According to SafeGraph, a POI is "a specific physical location which someone may find interesting" [37]. SafeGraph POIs include a variety of places, such as parks. Currently, not all parks are defined as individual POIs, especially small urban parks.

2.3. Methods

Parks that serve Tucson residents are the study objects. In addition to parks within Tucson's city limits, we also included parks within a 2-km distance to Tucson. In total, 201 parks managed by Tucson PRD and Pima County Nature and Park Resources were selected. However, only 173 parks are recognized as POIs in the SafeGraph dataset. We further excluded 27 school parks because these parks are only available to the public after school hours. In addition, we excluded six parks that miss park visit data and an additional mini park that presents unreasonably high volumes of visits, which is likely caused by the park location being next to a bus stop (i.e., data captured due to bus riders instead of park users).

In total, 139 parks (101 Tucson parks and 38 Pima County parks) were included in this study. Parks in Tucson are designed with different service radii, sizes, and amenities and are classified into different types following the classification criteria of the National Recreation and Park Association's standards with adjustments to fit Tucson's land area [29] (Table 1). For the Pima County parks included in this study, we classified these 38 parks using Tucson's classification criteria (see Table 1).

Table 1. Types of parks in Tucson, Arizona.

Park Type	Size (ha)	Service Radius (km)	Typical Amenities
Mini Park	0.04–0.3	0.4	Passive with no play equipment
Neighborhood Park	0.3–6.6	0.8	Play equipment, open turf area, and picnic tables
Community Park	6.2–15.8	2.4	Play equipment, lighted sports fields, aquatic centers, open turf area, picnic tables
Metro Park	18.2–47	4.8	Lighted sports field complexes, recreation centers, and aquatic centers
Regional Park	81.3–150.9	11.3	Diverse
River Park	28.5–130	0.8	Shared-use path with support amenities

3. Results

3.1. Park Management during the COVID-19 Pandemic (2020)

Figure 2 shows an overview of the Tucson PRD's response measures during the pandemic divided into three phases, and Tables 2 and 3 provide further details. These measures are in the context of the City of Tucson's and the State of Arizona's active roles in monitoring the presence of COVID-19.

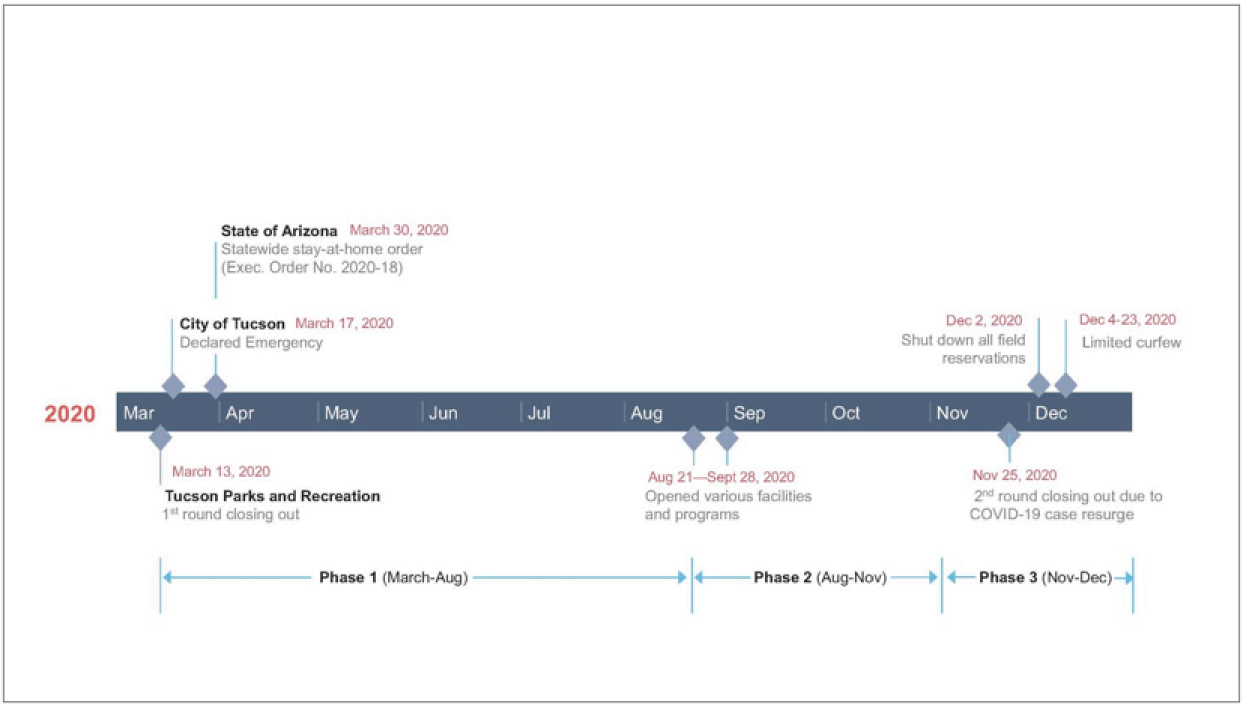

Figure 2. Overview of the City of Tucson's lockdown measures and Tucson Parks and Recreation Department's Park management adjustments during the COVID-19 pandemic (2020).

Table 2. City of Tucson and Tucson Parks and Recreation Department management adjustments during the COVID-19 pandemic in 2020.

	City of Tucson	Parks and Recreation Department
Phase 1 (March–August 2020)	17 March, Mayor Romero declared a local emergency. All service counters and lobbies and some parks closed; all recreation centers, aquatics facilities, youth programs, and senior programming closed in March.	13 March, canceled events, youth programs, regular center and aquatics activities, and slow pitch softball leagues. [1]
Phase 2 (August–November 2020)	Starting in August, the citywide reopening plan	Reopened ramadas, playgrounds, and other facilities for public use. [2]
Phase 3 (November–December 2020)	2–31 December, shut down all field reservations (e.g., practices, games, tournaments) 4–23 December, limited curfew	Starting 28 November, the second round of closures. Closed all ramadas and ceased to schedule fields for new games or tournaments. [3]

[1] Canceled events do not include scheduled leisure classes. Youth programs include SchoolzOut Camps, InBetweeners Club, and KIDCO. Senior programming was not canceled. [2] These include horseshoe pits and outdoor sports courts (starting in August), playgrounds (reopened 24 August), KIDCO programs (reopened 17 August), leisure classes outdoors offered at Reid and Udall parks (31 August–17 October), some swimming pools (reopened 28 October), and outdoor leisure classes (reopened January 2021). [3] The few local games already scheduled are allowed to continue.

Table 3. Tucson Parks and Recreation Department's management of facilities and amenities during the COVID-19 pandemic in 2020.

Facilities/amenities closed	Starting 31 March, close ramadas, gazebos, outdoor fitness equipment, basketball, bocce and volleyball courts, horseshoe pots, and splash pads. Starting 8 April, close tennis facilities
Facilities/amenities remain open	March-August, open golf courses, disc golf courses, tennis courts, dog parks, skate parks and rinks, urban fishing areas, open space, trails, walking paths, and a number of park restroom facilities.

3.1.1. Phase 1 (March–August 2020)

On 13 March, Tucson PRD responded swiftly to implement closure efforts. Soon after this, on 17 March, Tucson Mayor Romero declared a local emergency and enacted strict measures to close or delay the use of public facilities, including parks. On 30 March, Governor Ducey issued a statewide stay-at-home order to curb the virus's spread in Arizona (Exec. Order No. 2020-18). Parks are listed as essential services in this order.

Although Tucson parks remained open during the lockdown period, the PRD developed and implemented a series of guidelines and regulations that are in accordance with the recommendations of health authorities. These included (1) the closures of spaces or amenities where social distancing is difficult or impossible (e.g., public gathering spaces, playgrounds, public swimming pools), (2) canceling activity programs, special events, and classes, and (3) changing circulation throughout public spaces to encourage one-way movement on walking paths and other routes [38].

3.1.2. Phase 2 (August–November 2020)

After five months into the pandemic, Tucson started implementing a citywide reopening plan. Tucson PRD subsequently reopened selected facilities and activities in parks. It is worth mentioning that parks have served as sites for COVID-19 testing and places for distributing health information and materials. For example, free COVID-19 tests were made available on 7 August at Udall Recreation Center and from 12 September at EL Pueblo Recreation Center. On 17 October, free mask distribution began at Mission Manor Park. These response measures may increase visits to parks.

3.1.3. Phase 3 (November–December 2020)

However, COVID-19 resurged in November. Starting on 25 November, PRD closed all ramadas and ceased to schedule new games or tournaments. On 2 December, Tucson shut down all field reservations from 2 to 31 December. Furthermore, from 4 to 23 December, Tucson imposed a limited curfew from 10 p.m. to 5 a.m.

3.2. Annual Park Visits during the COVID-19 Pandemic (2019–2020)

Park visits fluctuated in response to park management measures. Starting from March 2020, park visits sharply decreased after the city declared a local emergency. As a result, park visits dropped to the lowest level in April 2020, even though April is the most popular month in Tucson in normal years (Figure 3, Table 4). In May, park visits gradually recovered and were observed at a low yet steady level until an increase in July. Beginning in August, park visits witnessed a more pronounced upward trend. As shown in Figure 3, August is the month that Tucson PRD started to reopen facilities and outdoor leisure classes. In November, however, park visits dropped again significantly, to a level much lower than that in 2019. This drop occurred because of the second pandemic wave and the closure of the park facilities.

The daily visits data show the same trend that started in mid-March: park visits decreased when Tucson PRD and the City of Tucson started to implement closing measures (Figure 4). The change in park visits from February to April is well reflected by PRD's response measures (see Tables 2 and 3).

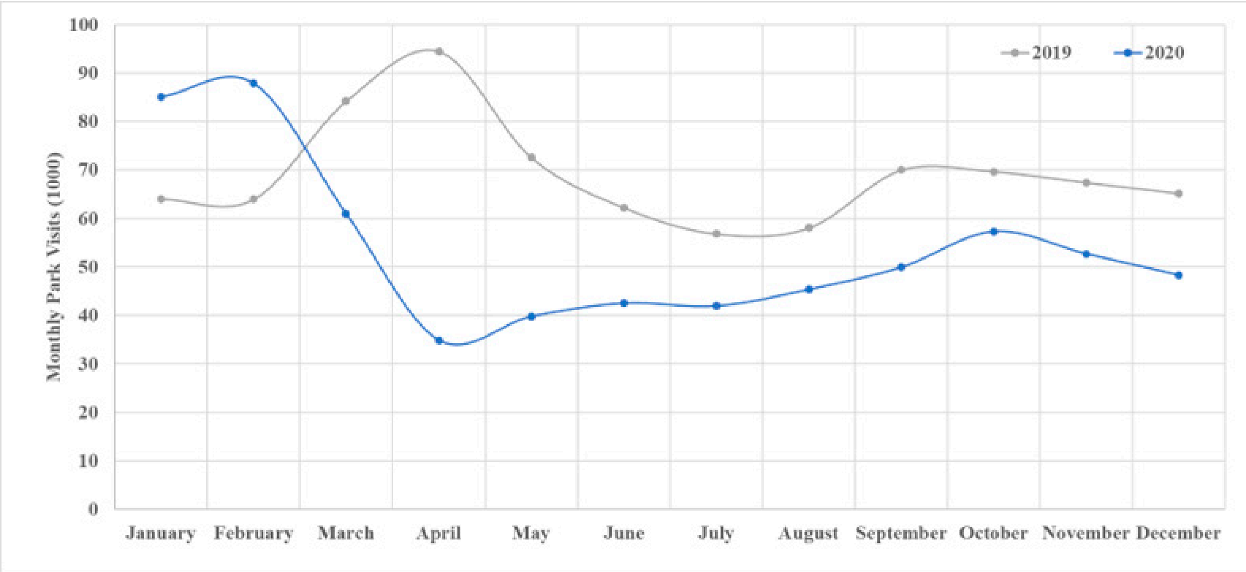

Figure 3. Monthly park visits in Tucson 2019–2020.

Table 4. Total park visits in Tucson 2019–2020.

Park Type	No. of Park	2019 Visit	2020 Visit	2019–2020 Change (%)
Mini park	17	19,882	15,927	−19.89
Neighborhood park	74	220,498	171,499	−22.22
Community park	19	138,193	110,545	−20.01
Metro park	15	213,242	153,101	−28.20
Regional park	9	111,673	87,363	−21.77
River park	2	114,374	100,976	−11.71
Total	139	823,766	644,007	−21.82

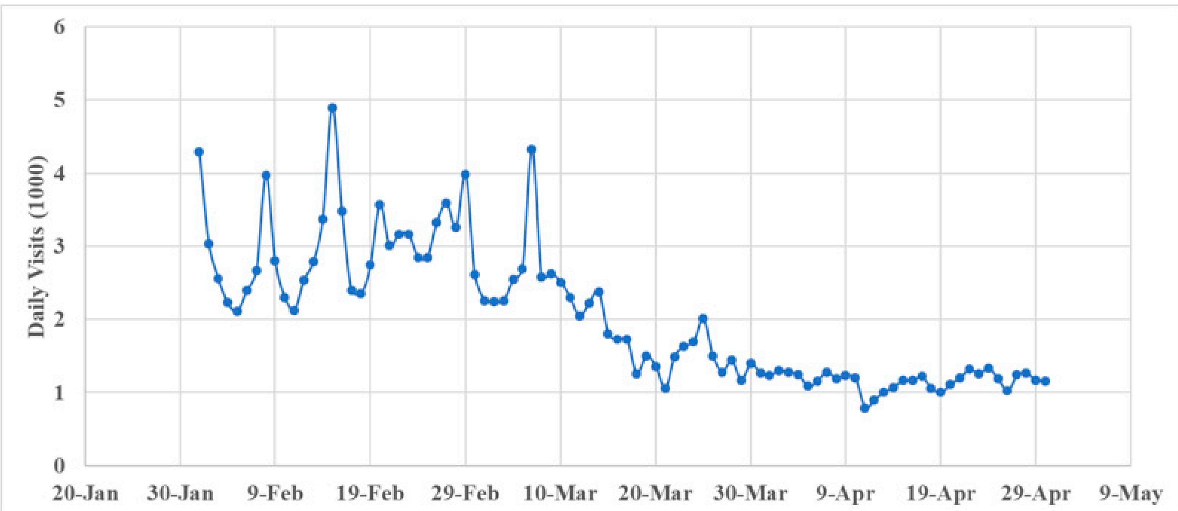

Figure 4. Daily visits in Tucson parks from February to April 2020 (early outbreak of the pandemic).

3.3. Weekdays and Weekend Visits

3.3.1. Overview Pre-Pandemic (2019) vs. Pandemic (2020)

Previous studies show that park visits peak over the weekend, particularly on Saturdays [27]. Based on 2019 data (pre-pandemic), results from this current study are consistent with previous studies [27]. In 2020 (during the pandemic), Saturdays continued to attract peak visits from January to May and then waned in June, and the peaks almost disappeared in July and August. In September, the peaks returned and continued until December (Figure A1).

In 2020, Saturday peaks still existed but at much weaker levels than in 2019. Saturday peak visits occurred in January and February but dropped quickly in March. In fact, park visits weakened in April–June. July Saturday visit levels became even lower than those on weekdays. From August to December, Saturday peaks reappeared. In short, the total number of visits and popular days changed substantially during the pandemic due to COVID-19 response measures.

3.3.2. Visits Per Park Type

Regional parks. As the largest park type, regional parks have high variations in visits in different months (Figure A2). In April 2019, weekend visits (especially Saturdays) reached the highest record of nearly 1400. The average number of daily visits in April was also much higher than that of other months. This is mainly because of the various park programs scheduled in April. The Southeast Regional Park contributed a large portion of this influx of visits because of the popular shooting range. In other months, the average daily visits were around 200 on weekdays and 200–600 on weekends. Saturday was the most popular day for visits. During 2020, there were less-pronounced peaks on weekends due to the stay-at-home executive order. In sharp contrast, from April to December 2020, there were only 20 visits on average on weekdays and 30 on weekends.

Metro parks. Metro parks presented a consistent pattern of daily visits, as well as peak visits on weekends throughout 2019 (Figure A3). In the cozy weather during spring and autumn, the weekend visits doubled those on weekdays. In 2020, this pattern remained true from January to early March. From mid-March to September, the average daily visits were slightly lower than those in 2019, with total visits of 200–400 on weekdays and weekends.

Community parks. Community parks presented different visit patterns on weekdays and weekends in the summer and other seasons (Figure A4). Besides the summer months, average daily visits were around 300–450 on weekdays and around 600 on Saturdays. In the summer, average weekday visits were similar to those in other seasons, but the visits dropped to 250–350.

Neighborhood parks. Neighborhood parks were popular from Tuesday to Saturday in 2019 (Figure A5). There were no apparent differences among seasons, with an average of 500–700 visits per day. November is the most comfortable month in Tucson outdoors. Neighborhood parks experienced peak visits on Saturdays. However, in March 2020, daily visits started to decline. From March to June, weekday visits remained stable but lower than in 2019, and weekend visits rapidly decreased. Beginning in August, Saturday visits increased but without apparent peaks. Weekday visits remained lower than those in 2019.

Mini-parks. Mini-parks attracted few visits, with average daily visits of around 40–80. Sundays continued to have low visits across different months in 2019 (Figure A6). In 2020, daily visits decreased to 20–50, while Sunday visits remained stable since the pandemic.

River/linear parks. River/linear parks had different patterns of park visits than other types of parks. Visits on weekends were consistently lower than those on weekdays in 2019, except during November (Figure A7). The average daily visits were around 280–380 on weekdays and 220–340 on weekends. In 2020, the number of visits decreased, but the pattern of visits on weekdays and weekends was similar to those in 2019.

3.4. Park Visits Change Per Park Type

Table 5 shows that the impact of the COVID-19 pandemic on park visits to different types of parks varied. Visits to parks decreased across the board in March and then gradually returned to levels close to the pre-pandemic conditions but in different months. Park visits peaked on Saturdays in neighborhood parks in August, in community parks in September, and in metro parks in October. Visits to river/linear parks were vastly different from other parks. River/linear parks in Tucson are similar to regional and metro parks in park areas, but the service radiuses are much smaller, only equivalent to that of neighborhood parks. River/linear park is the only type of park without discernable drops in visits on Saturdays. In other words, COVID-19 caused the least amount of impact on river/linear parks among the six types of parks in Tucson.

Table 5. Park visits change 2019–2020 per park type in Tucson, Arizona.

2019–2020 Visit Change	March–August (Phase I)	September–November (Phase II)	December (Phase III)
Mini Parks	−31%	−29%	−38%
Neighborhood Parks	−34%	−28%	−37%
Community Parks	−37%	−20%	−16%
Metro Parks	−42%	−25%	−22%
Regional Parks	−43%	4%	−2%
River Parks	−25%	−12%	−20%

3.5. Park Visits Recovery per Park Type

Table 6 shows the recovery process of park visits from 2019 to 2020. In 2020, visits across all park types decreased. At the onset of the pandemic (March and April), large parks (e.g., regional, metro, and community parks) experienced the most decrease. Visits to regional parks in April decreased by more than 80% compared to 2019. In contrast, small parks (e.g., mini-parks and neighborhood parks) were less impacted. Interestingly, river parks, as a type of large park, were least impacted in April. Starting in May, park visits gradually bounced back, although they remained lower than the pre-pandemic situations. Regional parks had the quickest recovery to nearly 80% in May and 95% in August 2019, respectively.

Table 6. Park visits recovery during the pandemic (2019–2020) per park type.

	Saturday Peaks in 2019	Saturday Peaks in 2020
Regional Park	Yes (Jan.–Dec.)	Yes (Jan.–Feb., May–Dec.)
Metro Park	Yes (Jan.–Dec.)	Yes (Jan.–Feb., Nov.–Dec.)
Community Park	Yes (Jan.–Dec.)	Yes (Jan.–Feb., Sept.–Dec.)
Neighborhood Park	No	Yes (Jan.–Feb., Aug.–Dec.)
Mini Park	No	No
River Park	No	No

River/linear parks also experienced a fine recovery, such that park visits in October reached around 93% in 2019. Similarly, mini-parks and neighborhood parks recovered from May to October but decreased again in November and December (see Figure 2). Community parks and metro parks had a slow but steady recovery, with a less than 20% decrease in park visits in October and November, respectively.

4. Discussions

4.1. Big Data for Park Studies

Unlike traditional data collected for park studies through surveys, interviews, and observations, big data are available in large volumes and offer a wide variety and high velocity of data [10,24,26,39]. Big data enable various types of park visit studies at the park-system level. Geotagged social media data (e.g., Twitter, Flickr, and Facebook) have been used to understand park use patterns and drivers. Recently, Google mobility data have been used to study park visit patterns during the COVID-19 pandemic at the county level in the US [21].

However, using social media data for park studies could be challenging in the future. With the increasing strict privacy requirements imposed by social media platforms, fewer social media users are sharing location information at high spatial accuracy levels. Also, social media data have limitations in representing the general population and capturing the spatial and temporal activity patterns [28,40].

Google mobility data became available in April 2020, containing aggregated and anonymized data from Google users. However, the location history setting is off by default [41]. It is largely unknown what percentage of Google users have their location history turned on to allow meaningful use of the location information [21]. The relatively short timeframe of the Google mobility dataset and the lack of representative baseline conditions make it challenging to examine park visitation changes [21]. Therefore, SafeGraph data demonstrate advantages to differentiating city- and neighborhood-level parks and green space uses under pandemic regulations.

Built on a previous study on Tucson parks [28,32], the current study further suggests that big cellphone data provided by SafeGraph can be a reliable data source to empower urban park visit studies and to examine park visitations and behavioral changes during the pandemic [12]. The trends of park visits revealed by the SafeGraph data matched the evolving management efforts of Tucson's PRD during the pandemic. In addition, the SafeGraph data can demonstrate daily visits at the individual park level, making it possible to assess the performance of a city's park system.

Nevertheless, SafeGraph data present several limitations in park studies. First, the number of park visits is based on the number of cellphone devices, not the number of people. Thus, it may not be well-captured youths as an important park user group. Second, small parks are not easily separated from their surrounding environment, especially in high-density urban areas. For example, some mini-parks are not considered POIs in the SafeGraph dataset and, therefore, are excluded from the analysis. Third, during the pandemic, parks as essential service areas are used for the distribution of masks and COVID-19 testing and treatment materials. It is difficult to differentiate the visits for medical purposes from recreational ones.

4.2. Impact of COVID-19 Pandemic across Different Park Types

The extensive linear boundaries of the river/linear parks make them easily accessible to visitors from nearby communities [28]. This advantage becomes stronger during the pandemic when residents prefer nearby nature that can support leisure and recreational needs in a safe manner. River/linear parks can offer better services than other parks because the popular biking and jogging activities in Tucson require minimum physical contact in river/linear parks.

Using big data, we observed behavioral changes in park visits are in accordance with the city's and state's response measures and that April witnessed the lowest level of park visitations following the responsive measures. Contrary to our research findings, previous studies found an increase in the use of parks and green space in cities in Asia, Europe, and America during the pandemic [23,39,40]. Green space is an umbrella term that includes parks, streetscapes, and other natural areas. In this sense, our results may not necessarily contradict previous findings on the increased use of green space. Instead of visiting parks beyond walking distance, residents may use local green streets or natural areas near their communities. For example, Ugolini et al. [42] reported that the reduction in park visits was accompanied by increased visits to gardens and other green space areas nearby. In the same vein, Venter et al. [40] found that in Oslo, Norway, residents used their streetscapes more often than peri-urban forests or parks during the pandemic.

4.3. Park Planning and Design for Future Pandemics

Park size and location have been essential factors in park planning and design. Studying park visits and park use during the pandemic sheds light on adaptive strategies for future pandemics. To curb disease transmission, larger areas provide a lower density of individual space and offer greater health and leisure benefits [43]. However, in Tucson, large parks (e.g., regional and metro) are mostly located in peripheral areas of the city. Due to constrained accessibility, these parks were less often used during weekdays in normal years. Not surprisingly, visits to large parks decreased the most during the pandemic.

Similar studies in Asian countries reported that residents prefer spacious nature parks close to urban centers [39]. Rice and Pan (2020) showed that residents in larger urban areas (50,000 population and greater) reduced the distance traveled for outdoor recreation significantly more than their counterparts in urban clusters (5000–50,000 population) and rural areas (less than 5000 population) [21]. In the same vein, in their study on the lockdown in Italy, Ugolini et al. [42] suggested that the closer people's homes are to urban green spaces, the more likely people will visit these spaces during the pandemic. These findings are supported by the current study on Tucson's park system, showing that parks in close proximity were generally popular before and during the pandemic.

5. Conclusions

We used SafeGraph cellphone big data to examine the park system performance in a mid-sized city, comparing before and during the COVID-19 pandemic park visits across different park types. We conclude that big data can be effective in performing a system-level investigation of park performance. In addition, big data can probe into people's visit behavioral changes at temporal scales, ranging from daily to monthly. Park users self-adjusted to the pandemic by reducing visits to large gathering spaces less often and evenly distributing their visits during the week, focusing on nearby, convenient spaces. A better understanding of these behavioral changes can help validate the efficacy of pandemic regulations. The study findings also have practical implications for park managers, planners, and designers aiming for sustainable park development in the post-pandemic era. Future research could consider integrating park visit data with behavioral analysis of park use in different types of parks. Finer-scale behavioral data, coupled with SafeGraph big data, can enable the exploration of the health benefits of urban parks.

Author Contributions: Conceptualization, S.L. and B.Y.; Methodology, S.L., B.Y. and H.L.; Validation, H.L.; Investigation, H.L.; Resources, B.Y.; Data curation, S.L.; Writing—original draft, B.Y.; Writing—review & editing, S.L., B.Y. and H.L.; Visualization, S.L.; Supervision, H.L.; Project administration, H.L.; Funding acquisition, B.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Arizona Institute for Resilience, from the Technology and Research Initiative Fund (TRIF)/Water, Environmental, and Energy Solutions initiative.

Data Availability Statement: The data presented in this study are available on request from SafeGraph, https://www.safegraph.com/points-of-interest-poi-data-guide (accessed on 13 October 2023).

Acknowledgments: We appreciate the support from the Tucson Parks and Recreation Department. We also thank the four anonymous reviewers for their constructive comments, which greatly improved this paper.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

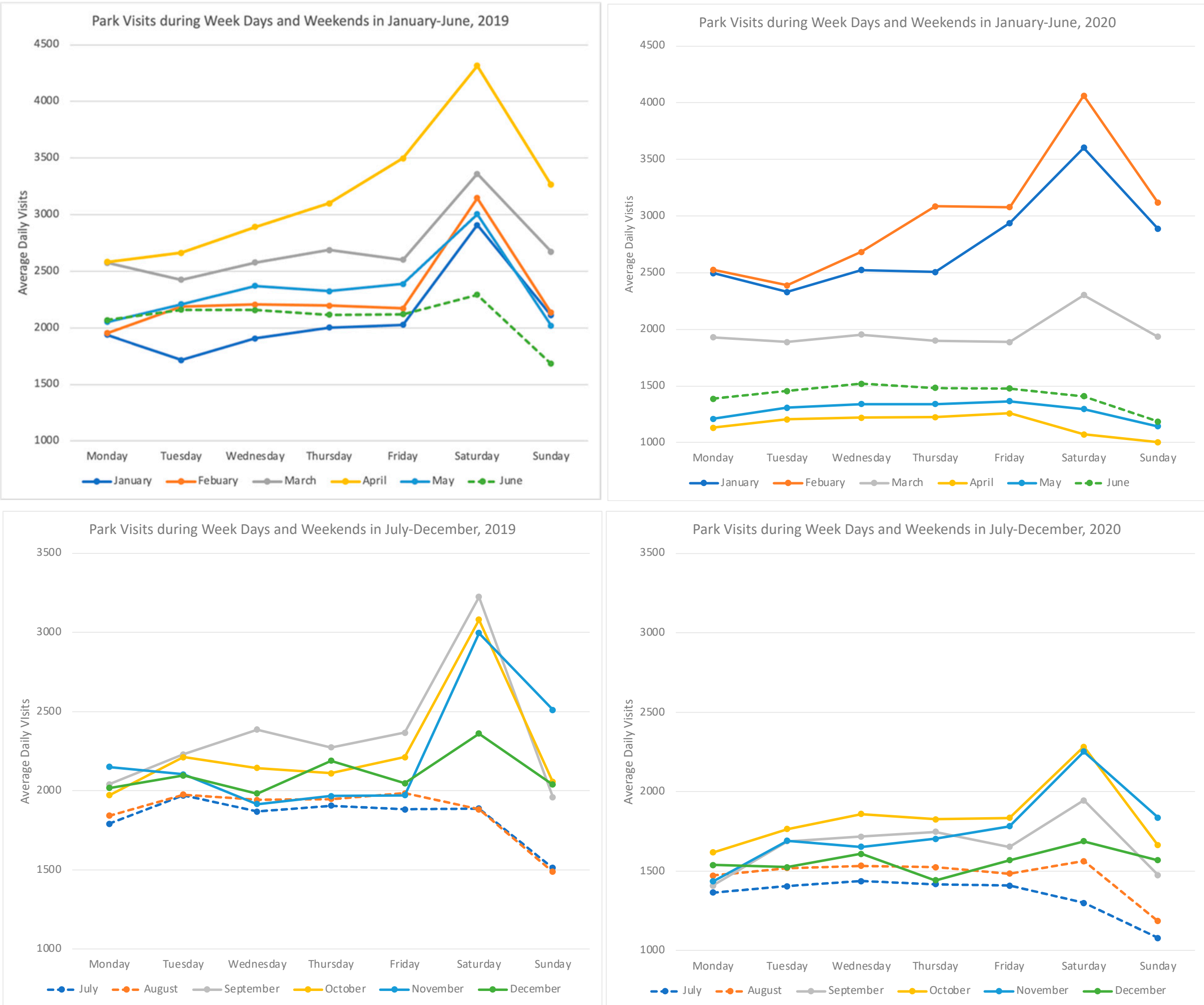

Figure A1. Park visits during weekdays and weekends in Tucson: pre-pandemic (2019) and during pandemic (2020).

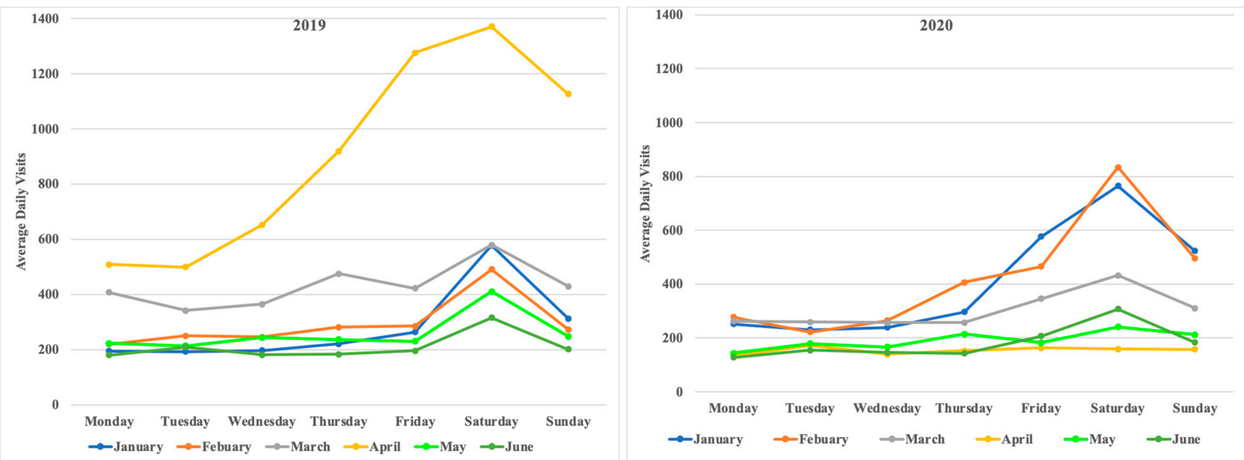

Figure A2. *Cont.*

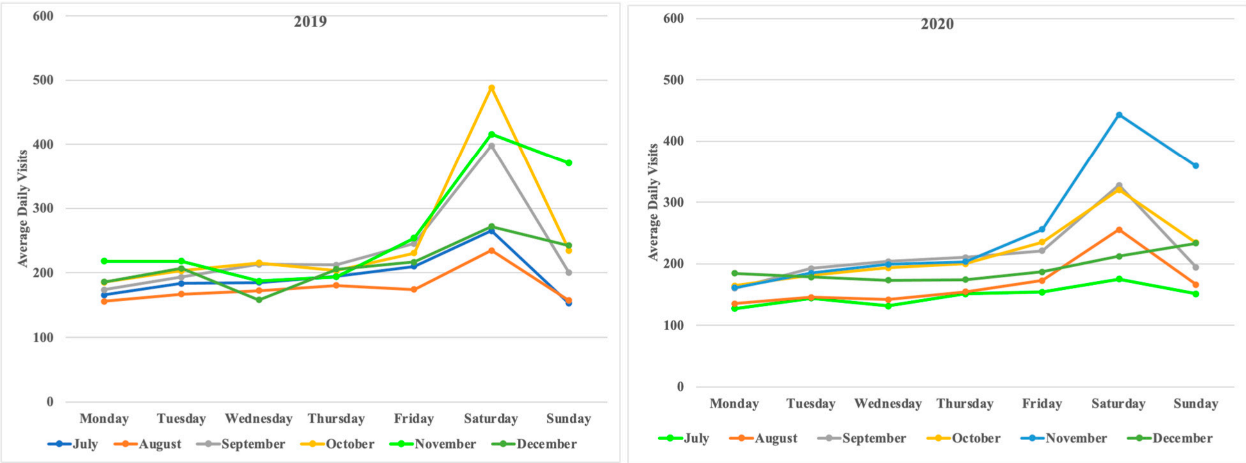

Figure A2. Regional park visits 2019–2020.

Figure A3. Metro park visit changes 2019–2020.

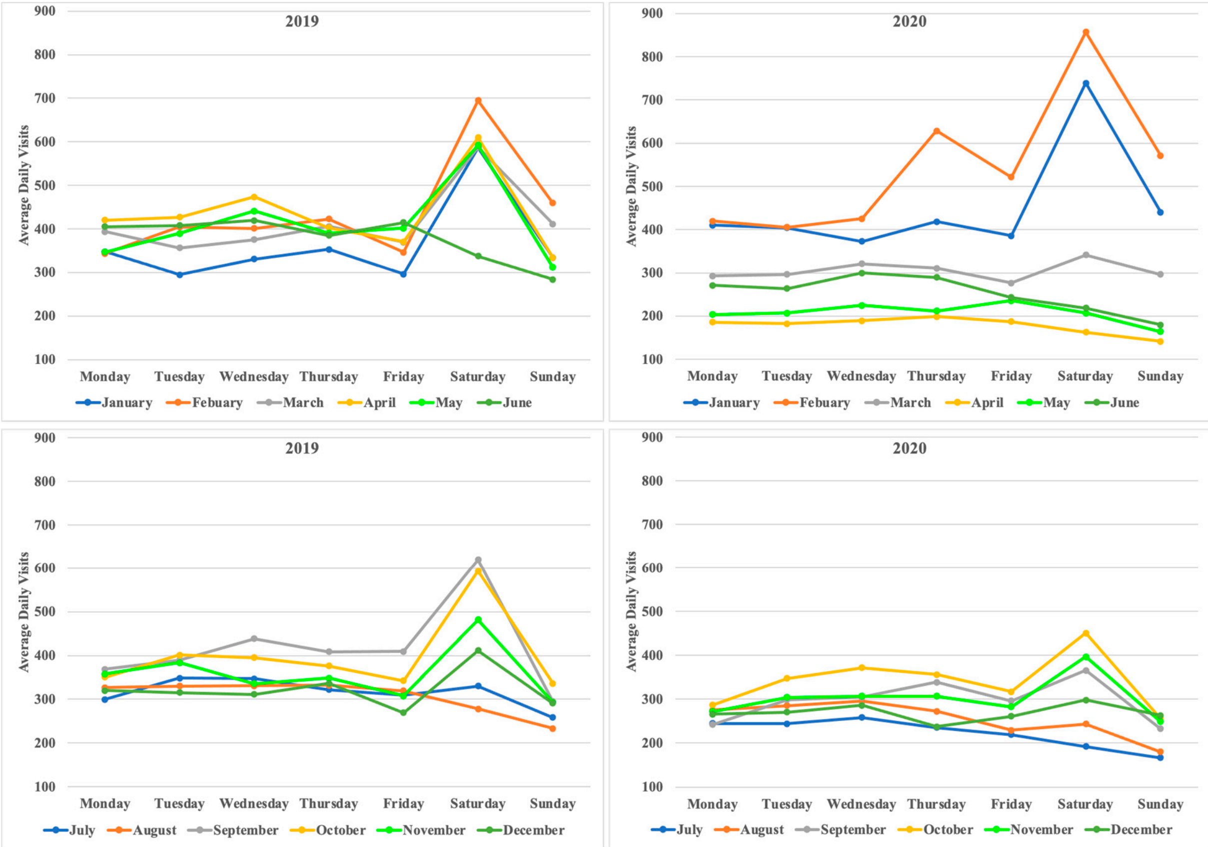

Figure A4. Community park visits 2019–2020.

Figure A5. Neighborhood park visits 2019–2020.

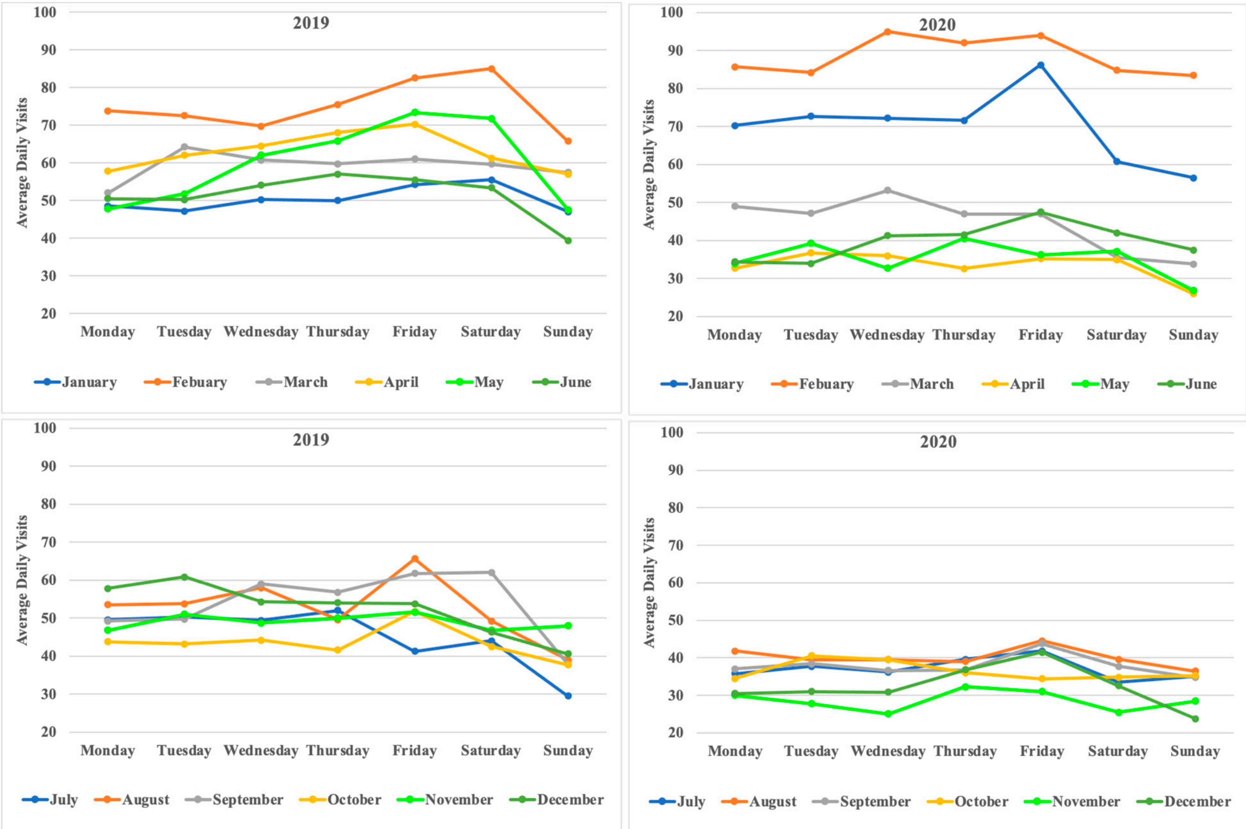

Figure A6. Mini-park visits 2019–2020.

Figure A7. River park visits 2019–2020.

References

1. Kaplan, R.; Kaplan, S.; Ryan, R. *With People in Mind: Design and Management of Everyday Nature*; Island Press: Washington, DC, USA, 1998.
2. Crompton, J.L. Parks and Open Space: The Highest and Best Use of Public Land? *J. Park Recreat. Adm.* **2001**, *19*, 133–154.
3. Pitas, N.A.; Barrett, A.G.; Mowen, A.J.; Graefe, A.R.; Godbey, G.C.; Sciamanna, C.N. The Relationship between Self-Rated Health and Use of Parks and Participation in Recreation Programs, United States, 1991 and 2015. *Prev. Chronic Dis.* **2017**, *14*, E02. [CrossRef]
4. Venter, Z.S.; Barton, D.N.; Gundersen, V.; Figari, H.; Nowell, M. Urban nature in a time of crisis: Recreational use of green space increases during the COVID-19 outbreak in Oslo, Norway. *Environ. Res. Lett.* **2020**, *15*, 104075. [CrossRef]
5. Mensah, C.A.; Andres, L.; Perera, U.; Roji, A. Enhancing quality of life through the lens of green spaces: A systematic review approach. *Int. J. Wellbeing* **2016**, *6*, 142–163. [CrossRef]
6. Chen, S.; Sleipness, O.; Christensen, K.; Yang, B.; Wang, H. Developing and testing a protocol to systematically assess social interaction with urban outdoor environment. *J. Environ. Psychol.* **2023**, *88*, 102008. [CrossRef]
7. Larson, L.R.; Zhang, Z.; Oh, J.I.; Beam, W.; Ogletree, S.S.; Bocarro, J.N.; Wells, M. Urban Park Use During the COVID-19 Pandemic: Are Socially Vulnerable Communities Disproportionately Impacted? *Front. Sustain. Cities* **2021**, *103*, 710243. [CrossRef]
8. McGinlay, J.; Holtvoeth, J.; Begley, A.; Dörstel, J.; Kockelmann, A.; Lammertz, M.; Jones, N. Perceived Social Impacts of Protected Areas, Their Influence on Local Public Support and Their Distribution across Social Groups: Evidence from the Eifel National Park, Germany, during the COVID-19 Pandemic. *Sustainability* **2023**, *15*, 10848. [CrossRef]
9. Jay, J.; Heykoop, F.; Hwang, L.; de Jong, J.; Kondo, M. Effects of the COVID-19 Pandemic on Park Use in US Cities. *medRxiv* **2021**, *preprint*.
10. Ding, Y.; Li, D.; Sang, H. Park Characteristics and Changes in Park Visitation before, during, and after COVID-19 Shelter-in-Place Order. *Sustainability* **2022**, *14*, 3579. [CrossRef]
11. Luo, W.; Baldwin, E.; Jiang, A.Y.; Li, S.; Yang, B.; Li, H.-Q. Effects of housing environments on COVID-19 transmission and mental health revealed by COVID-19 participant experience data from the All of Us research program in the United States: A case-control study. *BMJ Open* **2022**, *12*, e063714. [CrossRef] [PubMed]
12. Geng, D.C.; Innes, J.; Wu, W.; Wang, G. Impacts of COVID-19 pandemic on urban park visitation: A global analysis. *J. For. Res.* **2021**, *32*, 553–567. [CrossRef] [PubMed]
13. Slater, S.J.; Christiana, R.W.; Gustat, J. Recommendations for keeping parks and green space accessible for mental and physical health during COVID-19 and other pandemics. *Prev. Chronic Dis.* **2020**, *17*, E59. [CrossRef] [PubMed]
14. Lin, B.B.; Thompson, S.; Mitchell, R.; Astell-Burt, T.; De Leeuw, E.; Jalaludin, B.; Feng, X. Policymaker and Practitioner Perceptions of Parks for Health and Wellbeing: Scoping a Holistic Approach. *Sustainability* **2023**, *15*, 5251. [CrossRef]
15. Ibes, D.C. A multi-dimensional classification and equity analysis of an urban park system: A novel methodology and case study application. *Landsc. Urban Plan.* **2015**, *137*, 122–137. [CrossRef]
16. Liu, S.; Wang, X. Reexamine the value of urban pocket parks under the impact of the COVID-19. *Urban For. Urban Green.* **2021**, *64*, 127294. [CrossRef]
17. Volenec, Z.M.; Abraham, J.O.; Becker, A.D.; Dobson, A.P. Public parks and the pandemic: How park usage has been affected by COVID-19 policies. *PLoS ONE* **2021**, *16*, e0251799. [CrossRef]
18. Curtis, D.S.; Rigolon, A.; Schmalz, D.L.; Brown, B.B. Policy and Environmental Predictors of Park Visits During the First Months of the COVID-19 Pandemic: Getting Out While Staying in. *Environ. Behav.* **2021**, *54*, 487–515. [CrossRef]
19. Nickelsburg, M. Google location data for Seattle shows decline in work, transit and retail trips—But not park visits. *Geekwire*. 2020. Available online: https://www.geekwire.com/2020/google-location-data-seattle-shows-decline-work-transit-retail-trips-not-park-visits/ (accessed on 10 April 2020).
20. Jones, A. Mobility Data Shows a Massive Boost for Blount Parks after COVID-19 Outbreak. *The Daily Times*, 16 April 2020. Available online: https://www.thedailytimes.com/covid19/mobility-data-shows-a-massive-boost-for-blount-parks-after-covid-19-outbreak/article_6a4b3f1e-19fb-546e-a12a-91144b8bf02f.html(accessed on 20 April 2020).
21. Rice, W.L.; Pan, B. Understanding changes in park visitation during the COVID-19 pandemic: A spatial application of big data. *Wellbeing Space Soc.* **2021**, *2*, 100037. [CrossRef]
22. Niță, M.R.; Arsene, M.; Barbu, G.; Cus, A.G.; Ene, M.; Serban, R.M.; Stoia, L.N. Using social media data to evaluate urban parks use during the COVID-19 pandemic. *Int. J. Environ. Res. Public Health* **2021**, *18*, 10860. [CrossRef]
23. Pipitone, J.M.; Jović, S. Urban green equity and COVID-19: Effects on park use and sense of belonging in New York City. *Urban For. Urban Green.* **2021**, *65*, 127338. [CrossRef]
24. Sung, H.; Kim, W.R.; Oh, J.; Lee, S.; Lee, P.S.H. Are All Urban Parks Robust to the COVID-19 Pandemic? Focusing on Type, Functionality, and Accessibility. *Int. J. Environ. Res. Public Health* **2022**, *19*, 6062. [CrossRef] [PubMed]
25. Wu, H.C.; Lin, Y.C.; Chen, T.C.T. Leisure agricultural park selection for traveler groups amid the COVID-19 pandemic. *Agriculture* **2022**, *12*, 111. [CrossRef]
26. Kupfer, J.A.; Li, Z.; Ning, H.; Huang, X. Using mobile device data to track the effects of the COVID-19 pandemic on spatiotemporal patterns of national park visitation. *Sustainability* **2021**, *13*, 9366. [CrossRef]
27. Bertram, C.; Meyerhoff, J.; Rehdanz, K.; Wüstemann, H. Differences in the recreational value of urban parks between weekdays and weekends: A discrete choice analysis. *Landsc. Urban Plan.* **2017**, *159*, 5–14. [CrossRef]

28. Li, S.; Yang, B. How important are the park size and shape to a park system's performance? An exploration with big data in Tucson, Arizona, USA. *Socio-Ecol. Pract. Res.* **2021**, *3*, 281–291. [CrossRef]
29. City of Tucson. City of Tucson Parks and Recreation System Master Plan. 2016. Available online: https://www.tucsonaz.gov/parks/parks-and-recreation-system-master-plan (accessed on 15 March 2020).
30. Chow, W.T.; Brazel, A.J. Assessing xeriscaping as a sustainable heat island mitigation approach for a desert city. *Build. Environ.* **2012**, *47*, 170–181. [CrossRef]
31. Volo, T.J.; Vivoni, E.R.; Ruddell, B.L. An ecohydrological approach to conserving urban water through optimized landscape irrigation schedules. *Landsc. Urban Plan.* **2015**, *133*, 113–127. [CrossRef]
32. Yang, B.; Li, S.-J.; Jackson, G. Evolving Norms of Park Use during the Coronavirus Disease 2019 (COVID-19) Pandemic. In Proceedings of the CELA 2022 Evolving Norms Conference, Santa Ana Pueblo, NM, USA, 16–19 March 2022.
33. Gao, S.; Rao, J.; Kang, Y.; Liang, Y.; Kruse, J.; Dopfer, D.; Sethi, A.K.; Mandujano Reyes, J.F.; Yandell, B.S.; Patz, J.A. Association of mobile phone location data indications of travel and stay-at-home mandates with COVID-19 infection rates in the US. *JAMA Netw. Open* **2020**, *3*, e2020485. [CrossRef] [PubMed]
34. SafeGraph. What about Bias in the SafeGraph Dataset? 2021. Available online: https://www.safegraph.com/blog/what-about-bias-in-the-safegraph-dataset (accessed on 5 December 2021).
35. Glaeser, E.L.; Gorback, C.S.; Redding, S.J. How Much Does COVID-19 Increase with Mobility? Evidence from New York and Four Other U.S. Cities (No. w27519). *Natl. Bur. Econ. Res.* **2020**. Available online: https://scholar.harvard.edu/files/glaeser/files/howmuchdoescovid19increasewithmobility.pdf (accessed on 15 November 2020).
36. Weill, J.A.; Stigler, M.; Deschenes, O.; Springborn, M.R. Social distancing responses to COVID-19 emergency declarations strongly differentiated by income. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 19658–19660. [CrossRef]
37. SafeGraph (n.d.). Guide to Points-of-Interest Data. Available online: https://www.safegraph.com/points-of-interest-poi-data-guide (accessed on 10 October 2021).
38. Tucson PRD [Tucson Parks and Recreation]. 2020. Available online: https://www.facebook.com/TucsonParksandRecreation/ (accessed on 15 March 2021).
39. Lu, Y.; Zhao, J.; Wu, X.; Lo, S.M. Escaping to nature during a pandemic: A natural experiment in Asian cities during the COVID-19 pandemic with big social media data. *Sci. Total Environ.* **2021**, *777*, 146092. [CrossRef]
40. Venter, Z.S.; Barton, D.N.; Gundersen, V.; Figari, H.; Nowell, M.S. Back to nature: Norwegians sustain increased recreational use of urban green space months after the COVID-19 outbreak. *Landsc. Urban Plan.* **2021**, *214*, 104175. [CrossRef]
41. Google. COVID-19 Community Mobility Reports. 2020. Available online: https://www.google.com/covid19/mobility/ (accessed on 15 December 2020).
42. Ugolini, F.; Massetti, L.; Pearlmutter, D.; Sanesi, G. Usage of urban green space and related feelings of deprivation during the COVID-19 lockdown: Lessons learned from an Italian case study. *Land Use Policy* **2021**, *105*, 105437. [CrossRef] [PubMed]
43. Ekkel, E.D.; de Vries, S. Nearby green space and human health: Evaluating accessibility metrics. *Landsc. Urban Plan.* **2017**, *157*, 214–220. [CrossRef]