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Urban Park Use During the COVID-19 Pandemic: Are Socially Vulnerable Communities Disproportionately Impacted?

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The COVID-19 pandemic altered human behavior around the world. To maintain mental and physical health during periods of lockdown and quarantine, people often engaged in outdoor, physically distanced activities such as visits to parks and greenspace. However, research tracking outdoor recreation patterns during the pandemic has yielded inconsistent results, and few studies have explored the impacts of COVID-19 on park use across diverse neighborhoods. We used a mixed methods approach to examine changes in park use patterns in cities across North Carolina, USA, during the COVID-19 pandemic, with an emphasis on impacts in socially vulnerable communities (based on racial/ethnic composition and socioeconomic status). First, we surveyed a demographically representative sample of 611 urban residents during August 2020 to assess their use of outdoor park spaces before and during the pandemic. Second, we used cell phone location (i.e., geo-tracking) data to document changes in park visits within 605 socioeconomically diverse urban census tracts before (July 2019) and during (July 2020) the pandemic. Data from both methods revealed urban park use declined during the pandemic; 56% of survey respondents said they stopped or reduced park use, and geo-tracked park visits dropped by 15%. Park users also became more homogenous, with visits increasing the most for past park visitors and declining the most in socially vulnerable communities and among individuals who were BIPOC or lower-income. Our results raise concerns about urban park use during the COVID-19 pandemic and suggest pre-existing health disparities in socially vulnerable communities might be exacerbated by inequitable access and utilization of parks and greenspace.

Keywords: coronavirus, COVID-19, environmental justice, equity, greenspace, health, outdoor recreation, race

INTRODUCTION

In early 2020, a novel coronavirus (COVID-19) rapidly spread across the world, creating a global pandemic that altered human behavior and negatively impacted humans' physical health and mental health in unprecedented ways (Bao et al., 2020; Holmes et al., 2020). In many countries, early responses to the pandemic focused on comprehensive "lockdowns" or "stay-at-home" orders designed to prevent social contact that fuels virus transmission (Atalan, 2020). As research began to reveal that COVID-19 transmission risk was significantly lower in outdoor settings (Bulfone et al., 2020; Rowe et al., 2021), many cities began to re-open outdoor spaces with physical distancing mandates and other precautions (e.g., face coverings) in place (Venter et al., 2020). Following the elimination of popular indoor recreation activities, many urban residents around the world elected to spend time in places that remained accessible despite COVID-19 restrictions, such as public parks and greenspaces (Kleinschroth and Kowarik, 2020).

Parks and greenspaces improve quality of life for urban residents in many ways (Hartig et al., 2014; Larson et al., 2016). In terms of physical health, park use promotes active lifestyles that reduce the risk of cardiovascular disease and other chronic health conditions (Lachowycz and Jones, 2013; Twohig-Bennett and Jones, 2018). With respect to mental health, contact with parks and greenspace has been linked to improved cognitive functioning (Bratman et al., 2019), attention restoration (Kaplan, 1995), stress reduction (Hunter et al., 2019), emotional well-being (Capaldi et al., 2015), and social relationships (Jennings and Bamkole, 2019). The health promotion potential of urban parks, which was widely recognized before COVID-19 (Maller et al., 2006; van den Bosch and Ode Sang, 2017), is even more conspicuous during times of crisis. Across continents, public parks have been recognized as a unique source of community resilience during prolonged periods of lockdown and quarantine associated with COVID-19 (Grima et al., 2020; Samuelsson et al., 2020; Slater et al., 2020). Urban residents are more likely to suffer health impacts from the pandemic (Rader et al., 2020; Hubbard et al., 2021), and parks offer some respite from COVID-19 transmission risk and socially distanced life in cities (Johnson et al., 2021). Youth (Jackson et al., 2021) and adults (Cindrich et al., 2021; Poortinga et al., 2021) who maintained outdoor activity during the pandemic reported better health outcomes than those who did not go outside. With few alternatives available in cities around the world, park-based activities were one of the only options for urban residents hoping to sustain or enhance their health and well-being in early stages of the crisis (Ugolini et al., 2021).

Despite the health promotion value of parks during the pandemic, it is not yet clear how urban park use patterns shifted in the wake of COVID-19. Anecdotally, many park managers (especially in the US) reported a substantial increase in visitation [Pregitzer et al., 2020; The Trust for Public Land, 2020a; National Recreation Park Association (NRPA), 2021]. However, multiple studies tracking park use around the world during the pandemic have yielded inconsistent results. In an international survey across 49 US states and 14 countries, researchers found that frequency of outdoor recreation participation for adults in urban areas declined sharply throughout the first few months of the pandemic (Rice et al., 2020). Similar patterns have been documented for adolescents in the US (Jackson et al., 2021). However, in specific US states, some survey respondents have reported a rise in nature-based activity participation (Grima et al., 2020; Morse et al., 2020). A study using cell phone location data across the US found significant decreases in urban park visitation from the start of the pandemic through November 2020 (Jay et al., 2021), but another global study using a similar approach from February–May 2020 found general increases in urban park use across most countries (Geng et al., 2021). In both cases, patterns varied substantially based on local context due to different levels of disease prevalence and government-imposed closures and restrictions. In Norway, researchers found a rise in pedestrian activities in city parks and peri-urban forests during the pandemic (Venter et al., 2020). A study in the UK found slightly decreased park visitation during the first COVID-19 lockdown, but significantly increased park use in the second lockdown (Day, 2020). In Italy, urban park use declined during the pandemic and many residents lamented their limited access to greenspace (Ugolini et al., 2021). This conflicting evidence highlights the need for more research investigating the impact of the COVID-19 pandemic on urban park use.

Even less is known about if, or how, shifting recreation patterns during the pandemic varied across diverse communities. From a health perspective, communities with low socioeconomic status and communities with large populations of BIPOC (Black, Indigenous, or People of Color) residents are more likely to be negatively impacted, both physically and psychologically, by COVID-19 (Fortuna et al., 2020; Kim and Bostwick, 2020). Racial disparities in COVID-19 infection rates have also been documented, but those disparities are reduced in counties that have a higher ratio of green space (Lu et al., 2021). Even before the pandemic, however, environmental justice research has shown that low-income or BIPOC neighborhoods typically experienced limited access to parks, greenspaces, and other outdoor recreation resources (Sister et al., 2010; Rigolon, 2016; Nesbitt et al., 2019). If parks are located in low-income communities of color, they often tend to be of lower quality (Rigolon et al., 2018). Thus, the potential benefits of parks are not realized equitably across all segments of society (Jennings et al., 2016). As research in countries such as Russia and Australia has shown (Dushkova et al., 2021), disparities in urban park use and access might be magnified in the era of COVID-19. Pre-existing disparities, coupled with inequitable access to parks (a critical health promoting resource) during the pandemic, could exacerbate suffering and negative health outcomes in socially vulnerable populations.

Our study employed a mixed methods approach with two distinct datasets to examine shifting urban park use patterns during the COVID-19 pandemic from different angles and explore potentially magnified impacts on socially vulnerable communities. First, we used a survey of residents living in cities across North Carolina (NC), USA, to examine self-reported changes in park use during the pandemic and how they varied based on demographic attributes such as race/ethnicity and

income. Second, we used a separate sample of cell phone location (i.e., geo-tracking) data from urban areas across NC to examine shifts in park use before and during the COVID-19 pandemic, exploring links between park visitation and the social vulnerability of communities at the census tract level. By comparing these self-reported and overt measures of outdoor recreation behavior across different periods of time, we aimed to improve understanding of urban park use during COVID-19 across diverse communities.

STUDY SITE

Our mixed-method approach used primary data (in the form of a survey) and secondary data (in the form of geo-tracking data) to focus on residents of urban areas within the state of North Carolina (NC), USA. NC is the 9th most populous state in the US, and features two of the country's fastest growing cities, Raleigh and Charlotte (Ordonez, 2020). A majority (roughly 60%) of the state's 10.5 million residents live in urban areas. Furthermore, the NC population is racially and ethnically diverse (e.g., 71% White, 22% African American, 9% Hispanic/Latinx; US Census Bureau, 2021), and pronounced income disparities and inequality within the state were rapidly growing even before the pandemic (deBruyn, 2017). The state is also known for its popular and extensive network of state and municipal parks [NC Department of Natural Cultural Resources (NCDNCR), 2021]. For all of these reasons, NC is an ideal location for exploring how COVID-19 impacted urban park use of different groups and whether certain communities are more negatively impacted by the pandemic.

STUDY 1: SURVEY OF URBAN RESIDENTS

Methods

In August 2020, approximately six months after the start of the pandemic (and pandemic-related lockdowns) in the US, we conducted a web-based survey of residents across NC. The survey instrument, designed in collaboration with the NC Recreation and Parks Association, aimed to understand the influence of the pandemic on public outdoor recreation patterns. Using a *Qualtrics XM* panel, we collected data over a 1-week period from a demographically representative sample of approximately 900 adults (age 18 or older) across the entire state. *Qualtrics* draws potential respondents from a list of residents who sign up as paid online survey-takers through the *Qualtrics* website, allowing for rapid data collection while still approximating a probability sample at the appropriate scale (in this case, statewide; Boas et al., 2020). After data quality checks, 819 responses were considered valid based on survey completion rates of 100% and absence of straight-line responses. Because our analysis in this study only focused on residents of urban (45% of our sample) and suburban (30% of our sample) counties, we excluded responses from participants living in rural regions of the state. This yielded an effective sample size of 611 NC urban residents.

The survey instrument contained questions about outdoor recreational park use and factors affecting use. In this paper, our analysis focused specifically on the use of outdoor park spaces. To understand how people used parks, both before and during the pandemic, we asked respondents two related questions. First, we asked "Over the past year, prior to the COVID-19 pandemic, how often did you use open spaces/trails?" Response options based on scales used in previous studies of outdoor recreation participation frequency (Larson et al., 2011) included (1) "Never use," (2) "Rarely (annually, or a few times each year)," (3) "Occasionally (monthly or several times a month)," (4) "Often (weekly or several times a week)," and (5) "Very often (5 times or more a week)." In addition to open spaces and trails, we asked the same question about other types of recreation facilities (i.e., indoor facilities, aquatic facilities, programming and camps, outdoor fields and courts). However, at the time we collected data during Phase 2 of the pandemic (July–August 2020), many of those facilities in NC (e.g., indoor gyms, outdoor courts and fields, day camps, public playgrounds) remained closed or at limited capacity due to the Governor's statewide stay-at-home orders (Executive Order No. 155., 2020). Therefore, we chose to focus our analysis on the only park resources that were available to most residents: parks, nature preserves, greenways, and trails. To assess changes in park use during the COVID-19 pandemic, we asked, "During the COVID-19 pandemic (March to August 2020), how has your use of open spaces/trails changed?" Response options included (-2) "Stopped using altogether," (-1) "Used less," (0) "No change," and (1) "Used more."

TABLE 1 | Summary of demographic attributes for survey respondents ($n = 611$) from urban areas in North Carolina (NC), relative to all urban residents in NC.

	Proportion of survey sample	Urban census tracts in NC[a]
Age (in years)		
18–34	42.6%	31.0%
35–54	40.5%	26.0%
55+	16.9%	43.0%
Gender		
Male	41.1%	47.8%
Female	58.9%	51.9%
Race/Ethnicity		
White	65.3%	51.6%
Black	18.2%	29.7%
Hispanic	3.6%	11.6%
Other	12.9%	6.9%
Education		
High school or less	23.2%	32.9%
College/undergraduate	58.8%	53.9%
Graduate	18.0%	12.9%
Household Income		
$49,999 or less	37.9%	46.1%
$50,000-$99,999	37.5%	27.6%
$100,000 or more	20.7%	26.2%
Prefer not answer	3.9%	-

[a]*Demographic ratios for census tracts within urban boundaries across North Carolina calculated based on data from the American Community Survey (US Census Bureau, 2019).*

TABLE 2 | Results of multinomial logistic regression model[a] predicting demographic variables associated with sporadic and frequent park use (relative to non-use) among urban residents ($n = 611$) in North Carolina (NC), USA, prior to the COVID-19 pandemic.

	Sporadic users				Frequent users			
Variable	**B**	**SE**	**OR**	**Sig.**	**B**	**SE**	**OR**	**Sig.**
Income								
Ref = $49,999 or less								
$50,000–$99,999	0.648	0.276	1.91	0.010	0.887	0.301	2.43	0.003
$100,000 or more	0.847	0.401	2.33	0.030	1.534	0.412	4.64	<0.001
Education								
Ref = High school or less								
Undergraduate/College	0.719	0.279	2.05	0.010	0.861	0.311	2.37	0.006
Graduate	1.186	0.486	3.27	0.010	1.764	0.503	5.83	<0.001
Race/ethnicity								
Ref = White								
Black	−0.954	0.306	0.39	0.001	−1.025	0.335	0.36	0.002
Hispanic	−0.584	0.696	0.56	0.401	−0.019	0.691	0.98	0.978
Other	−0.078	0.394	0.93	0.842	−0.099	0.417	0.91	0.813
Gender								
Ref = Male								
Female	−0.102	0.269	0.90	0.704	−0.219	0.286	0.80	0.445
Age (in years)								
Ref = 18–34								
35–54	−0.440	0.292	0.64	0.131	−0.630	0.308	0.53	0.040
55+	−1.174	0.358	0.31	0.001	−2.013	0.407	0.13	<0.001

[a]*Reference category for dependent variables = Non-user; Nagelkerke's pseudo-R^2 = 0.238; B, parameter estimate; SE, standard error of B; OR, odds ratio; Sig. = p-value.*

We asked respondents to provide a variety of demographic information including gender (Man, Woman, Identify another way, Prefer not to say), age in years (18–24, 25–34, 35–44, 45–54, 55–64, 65 and over), education (Less than high school, High school graduate, Some college, Associate's degree, Bachelor's degree, Post-college/graduate degree), and race/ethnicity following common categories used by the US Census Bureau (American Indian or Alaskan Native, Asian, Black or African American, Hispanic/Latino or Spanish origin, Middle Eastern or Northern African, Native Hawaiian or Pacific Islander, White, Other, Prefer not to say). Respondents also provided their approximate annual household income in 2019 based on condensed categories used by the US Census Bureau (<$49,999, $50,000-$99,999, $100,000 or more, Prefer not to say), with the $50,000 threshold approximating the median household income for NC at the time of data collection (US Census Bureau, 2021). Respondents noted the county in which they lived (one of 100 in NC), and we used this information to determine if they were a resident of an urban (750+ people per square mile), suburban (250–750 people per square mile), or rural county (<250 people per square mile) based on NC demographic data (NC Rural Center, 2021).

To investigate demographic correlates of self-reported park use before and during COVID-19, we constructed two separate multinomial logistic regression models. We first reclassified pre-COVID-19 use of outdoor park spaces into three categories: no use (never), sporadic use (rarely or occasionally), and frequent use (often or very often). We then reclassified changes in park use during COVID-19 into three categories: decreased use (stopped using or using less), same use (no change), and increased use (using more). In both the before and during COVID-19 models, we examined associations between park use and socioeconomic attributes including gender, age, education, race/ethnicity, and income. We condensed demographic categories with small sample sizes to facilitate interpretation of results (e.g., combined certain income and racial/ethnic categories with smaller representation). Pre-COVID-19 park use was also included as an independent variable in the during COVID-19 model. We assessed model fit using Nagelkerke's pseudo-R^2, and we assessed statistical significance and effect size using odds ratios. To visually depict key demographic differences among variables of interest, we used bar charts and Chi-square tests to graphically represent park use before and during the pandemic. All analyses were conducted in R (R Core Team, 2014) using package nnet (Ripley and Venables, 2021).

Results

Demographic attributes of survey respondents suggested that our data collection approach yielded a diverse sample of NC residents that approximated the urban population in the state (**Table 1**). For example, 35% of respondents were BIPOC, 23% did not have a college degree, and 38% reported annual household incomes below $50,000. Overall, survey respondents were slightly more

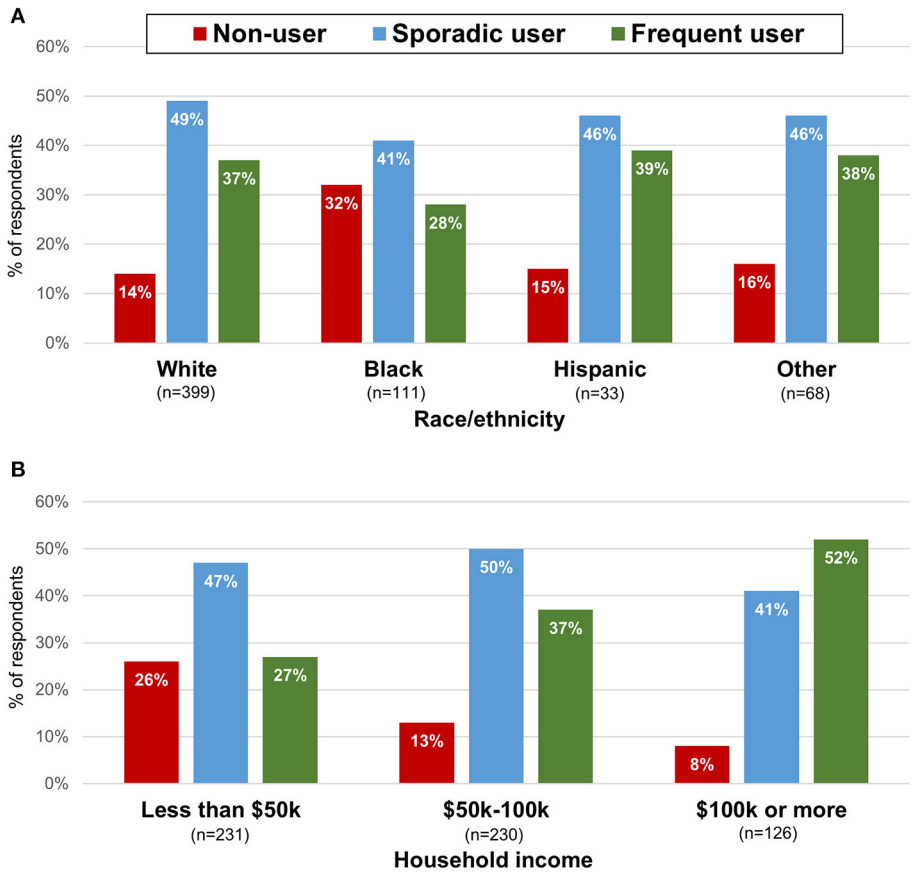

FIGURE 1 | Differences in pre-COVID-19 use of outdoor park spaces by **(A)** race/ethnicity ($X^2(6) = 18.5$, $p = 0.002$, Cramer's $V = 0.123$), and **(B)** household income ($X^2(4) = 35.5$, $p < 0.001$, Cramer's $V = 0.174$). Data are based on an August 2020 survey of urban residents in NC ($n = 611$).

likely to be 18–34 years old, female, white, and middle-income than average NC urban residents (**Table 1**).

According to self-reported survey data, 35.4% of respondents said they used parks frequently prior to COVID-19; 46.9% of respondents said they used parks sporadically and 17.7% never used parks before the pandemic. When examining demographic factors associated with pre-COVID-19 park use, we found that higher income and education levels were positively associated with park use (**Table 2**). Compared to the low-income reference group, respondents from the higher income groups were nearly five times as likely to be frequent park users. Pre-COVID-19 park use also varied by race. Before the pandemic, white respondents were more likely to be frequent or sporadic users of parks than any other racial/ethnic group, and they were significantly more likely to frequently use parks than Black respondents (**Table 2**). Respondents in the older age group were less likely to visit parks frequently compared to respondents in the youngest age group (**Table 2**). Bivariate comparisons of pre-pandemic park use with race/ethnicity and income highlight these demographic patterns (**Figure 1**).

During the COVID-19 pandemic, 55.7% of respondents reported stopping or decreasing use, 27.7% said their park usage did not change, and only 16.6% reported increased park use. The during COVID-19 regression model revealed many similar demographic patterns. Higher income park users were the least likely to stop using parks (**Table 3**). Relative to white respondents, BIPOC individuals were less likely to increase use of parks, though these differences were not statistically significant. Older respondents were less likely than younger respondents to increase use of parks. The most significant changes in park use during COVID-19 were linked to pre-pandemic park use patterns. Compared to non-users, frequent park users before the pandemic were 23 times as likely, and sporadic park users were nine times as likely, to increase their park use during COVID-19 (**Table 3**). In other words, any observed increases in park use during COVID-19 appeared to be driven by people who were already using parks regularly before the pandemic. Bivariate comparisons of park use changes during the pandemic with race/ethnicity, income, and pre-COVID park use frequency highlight these patterns (**Figure 2**).

TABLE 3 | Results of a multinomial logistic regression model[a] predicting demographic variables associated with changes in park use (increasing use or same use relative to stopping/decreasing use) among urban residents ($n = 611$) in North Carolina (NC), USA, during the COVID-19 pandemic.

	Same use/no change				Increased use			
Variables	**B**	**SE**	**OR**	**Sig.**	**B**	**SE**	**OR**	**Sig.**
Income								
Ref = $49,999 or less								
$50,000–$99,999	0.760	0.239	2.14	0.001	0.136	0.292	1.15	0.641
$100,000 or more	0.722	0.298	2.06	0.010	0.480	0.338	1.62	0.156
Education								
Ref = High school or less								
Undergraduate/college	−0.132	0.250	0.88	0.597	0.358	0.337	1.43	0.287
Graduate	−0.849	0.357	0.43	0.010	−0.121	0.430	0.89	0.779
Race/ethnicity								
Ref = White								
Black	−0.360	0.283	0.69	0.203	−0.732	0.360	0.48	0.044
Hispanic	0.242	0.527	1.27	0.646	−0.499	0.242	0.61	0.473
Other	0.037	0.302	1.04	0.901	−0.660	0.394	0.52	0.050
Gender								
Ref = Male								
Female	−0.086	0.215	0.92	0.691	0.001	0.261	1.00	0.990
Age								
Ref = 18–34								
35–54	0.080	0.234	1.08	0.734	−0.488	0.266	0.61	0.050
55+	0.296	0.300	1.34	0.324	−0.998	0.447	0.37	0.025
Pre-COVID								
Ref = Never use								
Sporadic users	−1.046	0.266	0.35	<0.001	2.151	1.032	8.60	0.010
Frequent users	−0.957	0.296	0.38	0.001	3.120	1.031	22.64	0.001

[a]*Reference category for dependent variables = Stopped or decreased use; Nagelkerke's pseudo-R^2 = 0.245; B, parameter estimate; SE, standard error of B; OR, odds ratio; Sig. = p-value.*

STUDY 2: GEO-TRACKING OF URBAN PARK USE

Methods

The second part of our study used cell phone location data, aggregated to the census tract level, to compare park use patterns within diverse urban neighborhoods at two different points in time: July 2019 (before the COVID-19 pandemic) vs. July 2020 (during the pandemic). We used location data originally collected by SafeGraph (www.safegraph.com), a commercial organization that measures frequency of visits to 4.4 million Points-of-Interest (POI) across the US at the census block level which include locations such as grocery stores, restaurants, and retail stores (Chang et al., 2021; SafeGraph, 2021a). The anonymized location data are primarily used for business (Hu et al., 2021), but SafeGraph also allows access for research purposes. SafeGraph derives precise geo-location data from 45 million smartphone devices in the US, yet protects the anonymity of public users by withholding personal information (Gao et al., 2020). SafeGraph assigns a code to each POI based on the North American Industry Classification System so that users can extract POIs based on specific business categories. Overall, the data from SafeGraph covers mobility patterns of 10% of the entire population in the US (SafeGraph, 2021b). During the COVID-19 pandemic, many researchers have explored shifting mobility patterns and disparities across diverse urban environments using SafeGraph data (Gao et al., 2020; Chang et al., 2021).

We were specifically interested in one type of POI: parks. Parks were first identified within the larger SafeGraph data category of "Nature Parks or Similar Places." We then filtered data to focus only on POIs with "park" in their name, with the goal of eliminating POIs, such as museums, that did not constitute outdoor public spaces and were likely to be closed during the pandemic. This resulted in 1773 unique park POIs across North Carolina. Based on location data for the geometric center (i.e., centroid) of each park, we assigned each park POI to a single US census tract (US Census Bureau, 2020). We used urban cluster boundaries for NC (n = 66; US Census Bureau, 2010) to exclude POIs in census tracts outside of urban areas. The total number of urban census tracts included in the analysis was 606, and the total number of urban park POIs across NC was 1,167 (**Figure 3**). At each urban park POI, SafeGraph used geo-tracking data to record the number of park visits (for visitors who used cell phone location services during their park visit). We examined

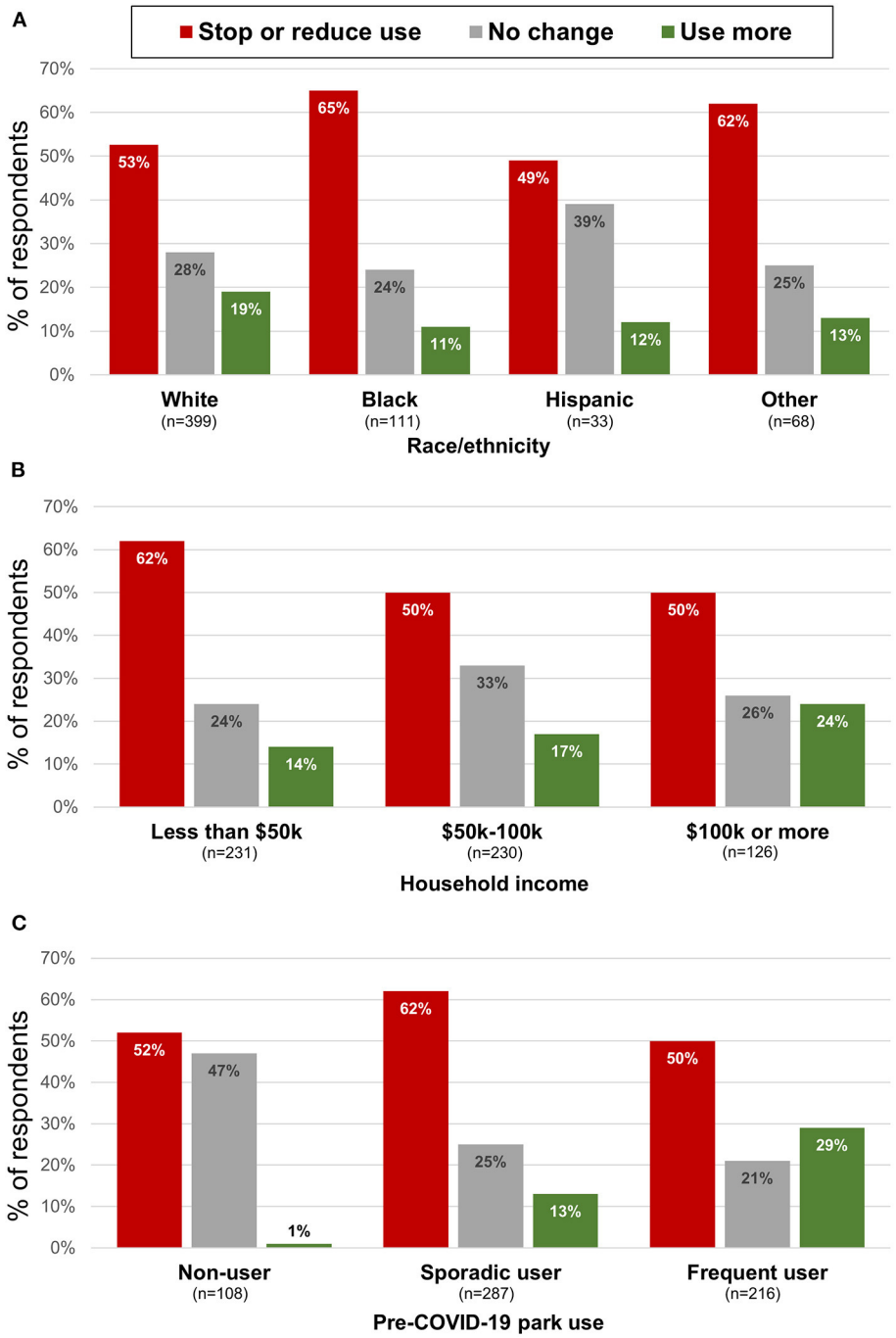

FIGURE 2 | Differences in outdoor park use changes during COVID-19 by **(A)** race/ethnicity ($X^2(6) = 10.2$, $p = 0.116$, Cramer's $V = 0.091$), **(B)** household income ($X^2(4) = 11.1$, $p = 0.025$, Cramer's $V = 0.097$), and **(C)** pre-COVID-19 park use levels ($X^2(4) = 60.7$, $p < 0.001$, Cramer's $V = 0.223$). Data are based on an August 2020 survey of urban residents in NC ($n = 611$).

data recorded during two different time periods: the entire month of July 2019 (from 12 a.m. on July 1 to 11:59 p.m. on July 31), which represented the pre-pandemic time block, and the entire month of July 2020, which occurred during the COVID-19 era. We focused on July because that month often represents the peak of summer park visitation. We used the sum of park visits for the entire month to represent park use at each individual POI in both years, and we aggregated park visits associated with individual POIs to the census tract level to match the spatial scale for other demographic variables. Thus, if there was more than one park

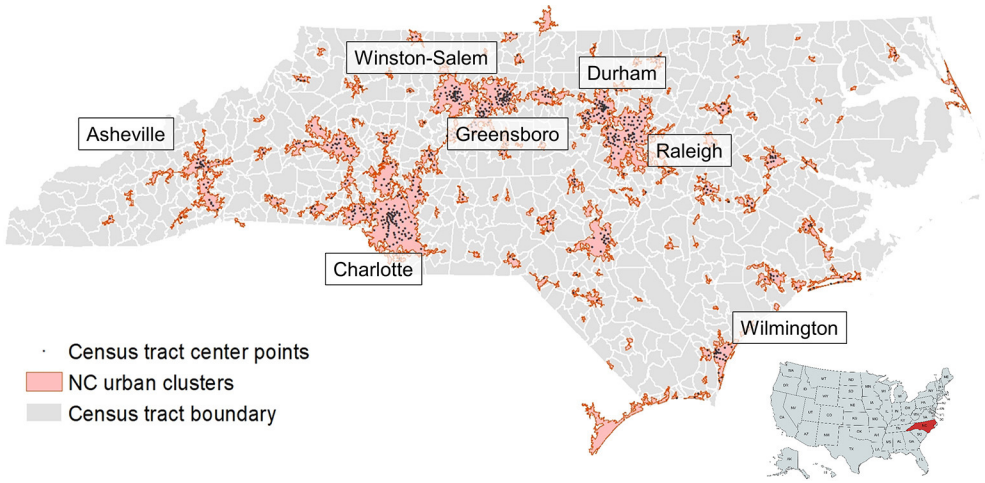

FIGURE 3 | Map of North Carolina (NC), USA, depicting park "points of interest" (POI) data used to geo-track park visits across urban clusters in the state in July 2019 and July 2020.

POI in a census tract, we added those visits together to represent the total number of park visits within that tract for each year (July 2019 vs. July 2020).

We used the social vulnerability index (SVI) [Centers for Disease Control Prevention (CDC), 2018] to characterize the socio-demographic attributes of urban neighborhoods. SVI is a spatial measure of vulnerability that accounts for factors such as socioeconomic status (SES), household age composition, and race/ethnicity. It is a compound index composed of 15 social factors based on data from the American Community Survey (ACS) (Flanagan et al., 2011). SVI measures have been used to predict community vulnerability and health risks due to COVID-19 [Centers for Disease Control Prevention (CDC), 2020]. Use of SVI enabled us to capture different components of social vulnerability simultaneously, thereby reducing the risk of multi-collinearity in regression models. We used three themes, or dimensions, of SVI that roughly aligned with demographic variables in our self-reported survey (Study 1). Although the survey and the geo-location data measured different aspects of park use at different times, both contained similar demographic variables that facilitated parallel exploration of park use patterns. For example, *socioeconomic status* included information about the ratio of residents below the poverty level, unemployment, income levels, and educational attainment (e.g., no high school diploma), aligning with education and household income variables on our survey. *Household age composition* included variables associated with age such as the number of minors and seniors in a house as well as disability metrics, aligning with the age variable on our survey. *Race/ethnicity/language* included information about the ratio of residents considered minorities due to racial and ethnic identity and those who speak English "less than well," aligning with the race/ethnicity variable on our survey. SVI scores for socioeconomic status and household age composition ranged from 0 to 4, and SVI scores for race/ethnicity/language ranged from 0 to 2, with higher scores indicating communities that are more vulnerable. We used SVI scores at the census tract level, matching the scale of park visitation data.

Because park use patterns are likely linked to park access and proximity (McCormack et al., 2010; Moran et al., 2020), we also integrated data regarding the number of parks within a census tract and the park ratio within the tract (i.e., the percentage of land within a census tract designated as parks). The data used to calculate park ratio was derived from ParkServe (The Trust for Public Land, 2020b), a geodatabase providing information about park size and park access to the public.

To examine overall changes in park use before and during the pandemic, we first compared average park visits across all urban census tracts in July 2019 vs. 2020 using a paired *t*-test. After these initial comparisons, we used a negative binomial regression model (for zero-truncated count data) to examine pre-COVID-19 park visits (July 2019) as a function of the three SVI themes (i.e., socioeconomic status, household age composition, and race/ethnicity), number of parks, and park ratio at the census tract level. We then applied the same model to examine park visits during COVID-19 (July 2020). To further explore how COVID-19 altered the park use, we ran a mixed effects logistic regression model that included the same independent variables, with binary park use change as the response variable. For that response variable, we subtracted pre-pandemic park visits from during-pandemic visits within each census tract and recoded change in use as 1 = increasing or no change (i.e., post—pre > 0), and 0 = decreasing (i.e., post—pre < 0). Although COVID-related physical distancing guidelines and restrictions remained in place in NC at the time of data collection (Executive Order No. 155., 2020), some degree of politically-driven variability in COVID-19 restrictions across municipalities in the state was still present (Adolph et al., 2021). We therefore added a random effect in each model to represent unique urban clusters (n = 66). We assessed model fit using McFadden's or Nagelkerke's

TABLE 4 | Results of negative binomial regression models[a] investigating associations between various census tract-level measures of social vulnerability (based on the social vulnerability index, SVI) and total park visits before and during the COVID-19 pandemic in North Carolina (NC), USA.

	Parks visits before COVID-19				Park visits during COVID-19			
Variables	**B**	**SE**	**β**	**Sig.**	**B**	**SE**	**β**	**Sig.**
SVI-SES[b]	−0.110	0.046	−0.13	0.017	−0.151	0.050	−0.17	0.003
SVI-AgeComposition[c]	−0.144	0.064	−0.10	0.030	−0.003	0.068	0.00	0.959
SVI-Race[d]	0.088	0.099	0.04	0.374	−0.171	0.103	−0.09	<0.001
Number of parks[e]	0.418	0.032	0.50	<0.001	0.315	0.034	0.38	<0.001
Park ratio[f]	4.776	0.668	0.28	<0.001	4.916	0.72	0.29	<0.001
McFadden's pseudo-R^2	0.478				0.403			

[a] *B, parameter estimate; SE, standard error of B; β, standardized estimate; Sig. = p-value; SVI scores based on Flanagan et al. (2011) and Centers for Disease Control Prevention (CDC) (2020).*

[b] *SVI-SES considers vulnerability based on socioeconomic status (below poverty, unemployed, income, no high school diploma).*

[c] *SVI-AgeComposition considers vulnerability based on household composition & disability (age 65 or older, aged 17 or younger, civilian with a disability, single-parent households).*

[d] *SVI-Race considers vulnerability based on minority status by race and ethnicity & language (minority, speaks English "less than well").*

[e] *Number of parks refers the total number of parks located within a census tract.*

[f] *Park ratio refers to the total proportion of land area within a census tract designated as park land.*

Model includes a random effect for different urban areas in the state.

pseudo-R^2, and we assessed statistical significance and effect size using parameter estimates and odds ratios. To visually depict differences in park use changes across neighborhoods with low and high social vulnerability (based on SVI scores), we created bar charts and conducted Chi-square tests comparing SVI level and park use change based on the following categories: more than 10% decrease in visits during COVID-19, no change in visits (visits remained within 10% of pre-pandemic levels), and more than 10% increase in park visits during COVID-19. We selected the 10% threshold to minimize the likelihood of misinterpreting random fluctuations around zero (i.e., changes in annual visitation between −10 and +10%). All analyses were conducted in R (R Core Team, 2014) using package lme4 (Bates et al., 2020).

Results

Across the 605 census tracts belonging to 66 urban clusters in North Carolina, we found an average of 1.9 (SD = 1.2) parks in each tract. The average size of park land in each census tract was 0.3 (SD = 0.6) km^2, and the average size of a tract was 9.4 (SD = 11.1) km^2, resulting in an average park ratio of 4.02% (SD = 5.92%).

Before the pandemic, the average number of total park visits within a census tract during July 2019 was 736.9 (SD = 1018.4). During the pandemic urban park visits dropped to 624.6 (SD = 955.8) per tract. Overall, park visits within each census tract during COVID-19 decreased by an average of 112.3 (SD = 838.2) compared to pre-COVID-19 park visits, a statistically significant decline [$t_{(604)} = -3.30, p = 0.001$] of over 15%. The average *socio-economic status* SVI score across all urban census tracts was 2.1 (SD = 1.1), the *household age composition* SVI score was 1.9 (SD = 0.7), and the *race/ethnicity* SVI score was 1.2 (SD = 0.5).

Before the COVID-19 pandemic, our negative binomial regression model showed that higher SVI scores for *socioeconomic status* and *household composition* were negatively associated with park visits at the census tract level, while the number of parks and park ratio were positively associated with park visits (**Table 4**). We observed similar patterns during the pandemic, as *socioeconomic status* remained inversely related to park visits (lower SES = fewer park visits), and the number of parks and ratio of parkland in a census tract were positively linked to visits. However, during the pandemic, higher SVI scores based on *race/ethnicity* were also negative correlates of park visitation (**Table 4**). In our logistic regression model where change in park visits was the binary dependent variable, we found

TABLE 5 | Results of mixed effects logistic regression model[a] investigating associations between various census tract-level measures of social vulnerability (based on the social vulnerability index, SVI) and changes in park visits before and during the COVID-19 pandemic (1 = increase or no change in visits, 0 = decrease in visits) in North Carolina (NC), USA.

	Increase in park visits during COVID-19			
Variables	**B**	**SE**	**OR**	**Sig.**
SVI-SES[b]	−0.050	0.128	0.94	0.676
SVI-AgeComposition[c]	0.263	0.180	1.30	0.144
SVI-Race[d]	−0.583	0.260	0.56	0.025
Number of Parks[e]	−0.289	0.089	0.75	0.001
Park ratio[f]	−1.179	1.820	0.31	0.518
Nagelkerke pseudo-R^2	0.172			

[a] *B, parameter estimate; SE, standard error of B; β, standardized estimate; Sig. = p-value; SVI scores based on Flanagan et al. (2011) and Centers for Disease Control Prevention (CDC) (2020).*

[b] *SVI-SES considers vulnerability based on socioeconomic status (below poverty, unemployed, income, no high school diploma).*

[c] *SVI-AgeComposition considers vulnerability based on household composition & disability (age 65 or older, aged 17 or younger, civilian with a disability, single-parent households).*

[d] *SVI-Race considers vulnerability based on minority status by race and ethnicity & language (minority, speaks English "less than well").*

[e] *Number of parks refers the total number of parks located within a census tract.*

[f] *Park ratio refers to the total proportion of land area within a census tract designated as park land.*

Model includes a random effect for different urban areas in the state.

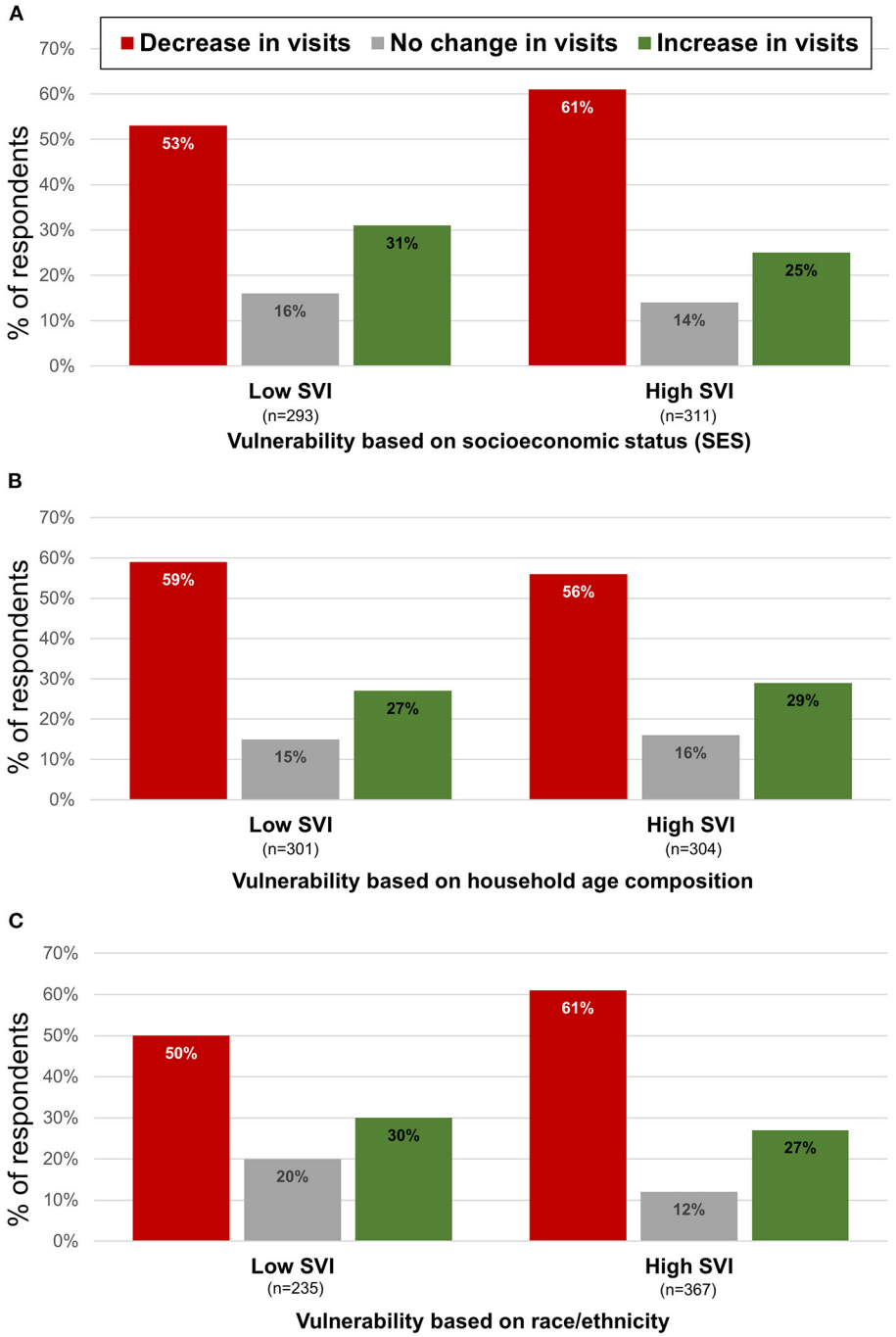

FIGURE 4 | Changes in geo-tracked park visits before (July 2019) and during (July 2020) the COVID-19 pandemic in urban census tracts across the state of North Carolina (NC), USA, based on social vulnerability of communities. Social vulnerability index SVI scores (Flanagan et al., 2011) were coded as low or high based with the midpoint of each index as the cutoff point (e.g., ≥ 2.0 = high vulnerability, < 2.0 = low vulnerability). Park visit changes were grouped into three categories: more than 10% decrease in visits during COVID-19, no change in visits (visits remained within 10% of pre-pandemic levels), and more than 10% increase in visits during COVID-19. Differences are depicted by **(A)** SVI-SES ($X^2(2) = 3.9$, $p = 0.140$), **(B)** SVI-AgeComposition ($X^2(2) = 0.64$, $p = 0.728$), and **(C)** SVI-Race ($X^2(2) = 8.1$, $p = 0.018$). Park visit data are derived from cell phone locations within 605 socio-economically diverse urban census tracts across NC.

that social vulnerability based on *race/ethnicity* was a significant predictor: census tracts with large BIPOC populations were more likely to experience declines in park visitation (**Table 5**). We observed a similar, but not significant, trend based on *socioeconomic status*. We also found that the number of parks in a census tract was negatively associated with park visit changes, such that more parks in a neighborhood resulted in a higher likelihood of park visits declining during COVID-19 (**Table 5**).

Bar charts comparing park use changes across census tracts with high and low levels of social vulnerability support these patterns, showing that park visits were more likely to decrease when SVI scores were high for race/ethnicity and SES (**Figure 4**).

DISCUSSION

Our study of cities across North Carolina (NC), USA, yielded two main findings regarding urban park use patterns during the COVID-19 pandemic. First, we discovered significant declines in urban park visitation since the start of COVID-19. This pattern was consistent across different data collection methods, including self-reported survey responses and geo-tracking data from cell phones. Second, declines in park visitation during the pandemic were more pronounced in socially vulnerable communities. This is alarming because these same communities, defined by residents who are BIPOC and/or low socioeconomic status, also reported lower levels of park use before the pandemic. Therefore, the COVID-19 pandemic appeared to exacerbate pre-existing disparities in park use, raising significant environmental justice concerns that might compound the COVID-related health crisis facing marginalized populations (Uchiyama and Kohsaka, 2020; Burnett et al., 2021; Dushkova et al., 2021).

Our results showing a drop in urban park visitation during the pandemic mirror some studies documenting declines in urban park use over the same time period (Jay et al., 2021), but they appear to contradict other reports indicating a rise in park visits during COVID-19 (Day, 2020; Pregitzer et al., 2020; Venter et al., 2020). Such discrepancies might be explained in several ways. Studies at different spatial scales have revealed variable patterns of outdoor recreation and park use since the start of the COVID-19 pandemic, ranging from unprecedented surges to dramatic declines (Geng et al., 2021). Shifts in park visitation have been linked to government policies during the pandemic, with stringent regulations and public health messaging deterring outdoor recreation in some places while encouraging it in others (Slater et al., 2020). In NC, most urban parks closed in the early stages of the pandemic. However, by July and August of 2020, most outdoor park spaces in cities were open with physical distancing guidelines in place. Parks in NC were therefore accessible during the time of data collection, although some degree of skepticism and concern regarding virus transmission in public spaces likely persisted, potentially curtailing visits (Weed and Foad, 2020).

Our data revealed another possible explanation for the rise in urban park visits seen in some cities around the world: more frequent visitation from past park visitors. We found that people who used parks frequently (i.e., on at least a weekly basis) were 23 times as likely to increase their park use during the pandemic than people who never used parks before COVID-19. Sporadic park users before the pandemic were nearly nine times as likely to increase park use during COVID-19. Perhaps these past users recognized the variety of benefits that parks can provide, and viewed parks as a critical health resource in these challenging times (Xie et al., 2020; Poortinga et al., 2021; Pouso et al., 2021). Or perhaps additional leisure time associated with workplace and school closures created more opportunities for higher-income outdoor recreation enthusiasts, already likely to visit parks before the pandemic, to pursue the activities they enjoy (Venter et al., 2020). Meanwhile, recreation and leisure opporunities for lower-income people, who were less likely to visit parks before COVID-19 and more likely to experience pandemic-related pressures, likely remained elusive (Yerkes et al., 2020). In any case, it appears that circumstances surrounding the COVID-19 pandemic did not attract many new users to urban parks in NC. In fact, only 1% of statewide survey respondents who did not visit parks previously started using them during COVID-19. These findings cast doubt on claims the pandemic has expanded the appeal of public parks across the general population (Grima et al., 2020; The Trust for Public Land, 2020a; Venter et al., 2020), and they underscore the need for more effective communication to reach underserved audiences in and around parks (Lee et al., 2020). While the health benefits of parks may be more evident due to COVID-19 (Razani et al., 2020; Slater et al., 2020), it does not appear that all segments of the American public are realizing those benefits.

Both survey and geo-tracking data indicated post-pandemic declines in park use were most significant in socially vulnerable communities, highlighting environmental injustices. BIPOC (particularly African American) and low-SES neighborhoods entered the pandemic with lower levels of park use, and it was these same individuals (and communities) that were more likely to experience decreasing park visitation during the pandemic. Among BIPOC respondents, only Hispanic/Latinx respondents maintained visitation levels comparable to white respondents during the pandemic, highlighting the particularly critical role of public parks as recreation destinations with the Hispanic community (Flores and Sanchez, 2020). Our findings mirror previous studies in the United States exposing race and income-related inequities related to greenspace access (Sister et al., 2010; Nesbitt et al., 2019) and park quality (Rigolon et al., 2018) in both urban and non-urban settings (Winter et al., 2020). Results also reflect disparities in park use and access to greenspace that have been observed in other countries during the pandemic (Burnett et al., 2021; Dushkova et al., 2021). In US-based studies, researchers found park visits during the pandemic decreased the most in areas where park availability was low (Curtis et al., 2021) and more residents were BIPOC (Jay et al., 2021). In places where park distribution and access is inequitable (i.e., socially vulnerable neighborhoods), alternative pathways to nature and outdoor recreation may be critical. Contact with any form of greenery, from views of vegetation to community gardens, can produce positive health outcomes during the pandemic (Dzhambov et al., 2021; Robinson et al., 2021; Soga et al., 2021). These nature-based experiences are especially strong correlates of well-being within BIPOC populations (Tomasso et al., 2021). To create new types of public outdoor recreation space, some cities have started open and shared street initiatives during the pandemic (Hanzl, 2020; Scott, 2021). Similar innovations may be needed in marginalized communities to foster healthy and active lifestyles when other park-based options are limited. Research has shown that historically marginalized and socially vulnerable populations are more likely to experience the physical

and mental health impacts of COVID-19 (Fortuna et al., 2020; Kim and Bostwick, 2020). Our evidence supports assertions that, within these communities, limited and diminishing use of park spaces during the pandemic could potentially widen health these disparities (Honey-Rosés et al., 2020; Taylor et al., 2021).

Limitations and Future Research

Several limitations should be acknowledged when interpreting the results of our study. Although our analysis synthesized results based on multiple methods of data collection, it only examined park use in urban areas of one US state. Other research has shown substantial variation in park use patterns across diverse geographic areas during COVID-19 (Geng et al., 2021), and our inferences should be extrapolated with caution. Furthermore, our study did not explore mechanisms behind observed imbalances in park use across demographic groups. Contextual factors that might impact park use in minority communities include park quality (Cohen et al., 2019), the built environment surrounding parks (Cutts et al., 2009), crime (Marquet et al., 2019), and other lifestyle factors (e.g., illness, income loss, childcare changes) that shifted in the wake of the pandemic—especially within socially vulnerable communities suffering disproportionate physical and psychological impacts from COVID-19 (Ruprecht et al., 2021). Although we controlled for differences across urban areas, we did not directly explore how different public health regulations in the wake of COVID-19 might have influenced park use (Geng et al., 2021). And we did not account for other concurrent events, such as the social justice movement in the US, that might have impacted the way different populations—especially BIPOC communities—utilize public spaces (Hoover and Lim, 2021). Future research could explore all of these relationships.

Several limitations associated with our distinct methodological approaches should also be noted. The term "park" was not defined for respondents on the self-reported surveys, and was therefore subject to different interpretations. Studies have shown that many members of the general public know very little about parks, and often conflate them with—or exclude them from—other types of recreation facilities (Spotts and Stynes, 1984). However, we specifically asked about use of five different types of park facilities in our survey, which should have minimized confusion. The one type of park facility emphasized in this analysis (i.e., open space and trails) was the only one that remained open in NC throughout most of the pandemic, but future studies could explore use of other types of park facilities as they reopen. Recall bias might have impacted self-reported park use frequency before the pandemic. However, researchers are increasingly using retrospective pre-post designs like the one we employed to effectively measure changes in outcomes over time when a baseline measure does not exist (Geldhof et al., 2018). Additionally, it is possible that Qualtrics online survey takers did not accurately reflect the general population in NC, but other studies have shown Qualtrics panelists effectively served as representative samples at the state and national levels (Boas et al., 2020).

With respect to cell phone data, all of the typical limitations of geo-tracking apply, with certain groups such as older residents less likely to be represented (Coston et al., 2021). Overall, although only 10% of urban residents are represented in SafeGraph data, the company's sampling is highly correlated with true census populations (Kang et al., 2020; SafeGraph, 2021b). Our filtering process only focused on POIs with "park" in the title, which might have inadvertently excluded certain types of public recreation resources, such as greenways. Thus, some forms of park use might have been overlooked due to SafeGraphs's imperfect classification system (Jay et al., 2021). Because we used the number of visits, there could be repeated data representing multiple visits a day from the same user at a park POI. We were not able to discern if the park user traveled from outside the local census tract to visit the park. If this was the case, then a park visitor may not necessarily reflect the demographic characteristics of the neighborhood in which a park is located. However, studies have shown that most urban park users live within close proximity to the parks they visit (Kaczynski et al., 2014; Moran et al., 2020). Cell phone location data may be less readily available in socially vulnerable communities, leading to underestimates of park visitation in these neighborhoods using Safegraph data. Even if this were true, however, the relative change in park use before and during COVID-19 should not have been significantly impacted. Finally, future research could dissect the somewhat unexpected finding that more parks in an urban census tract resulted in a greater likelihood of declining park visits during the pandemic. This could mean that quality is more important than quantity when predicting park use (Rigolon, 2016), or that numerous smaller parks may be viewed as more risky and less appealing during COVID-19 when compared to larger parks where physical distancing is easier to achieve (Mateer et al., 2021).

CONCLUSION

Despite many reports indicating urban park use increased during the COVID-19 pandemic, our survey and geo-tracking of the general public in cities across NC, USA, suggest this was not the case. Not only did urban park use in NC decline during the pandemic, but it became more homogenous. The same individuals and communities more likely to visit parks before COVID-19, white and high-income residents, were even more likely to use parks during the pandemic. Results expose broad concerns about urban park use (and subsequent health impacts) during the COVID-19 pandemic and raise additional questions about how those negative impacts might be inequitably distributed across diverse communities. Our findings underscore the need for more research on urban park use and associated benefits during the pandemic, and they highlight the importance of planning, managing, marketing, and investing in public park spaces that serve all segments of society.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Institutional Review Board of North Carolina State University (IRB 21141). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

LL and JB are the principal investigators of the study and oversaw conceptualization of the study, funding acquisition, and survey instrument design. KJL, JC, KS, JAH, LM, MC, and MW helped develop the study protocols. ZZ, JO, and WB led the analysis of primary and secondary data, with input from LL and SO. LL and ZZ led the writing of the original manuscript draft, and including data visualizations. All authors contributed to the final draft of the article and approved the submitted version.

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