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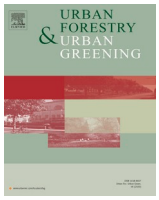

Changes in visits to green spaces due to the COVID-19 pandemic: Focusing on the proportion of repeat visitors and the distances between green spaces and visitors' places of residences

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ABSTRACT

Through a quantitative approach, this study aimed to clarify the changes in the number of visitors and visits to green spaces according to green space type before and after the COVID-19 pandemic. We explored the changes in the proportion of repeat visitors and the distance between green spaces and visitors' places of residence. We used KDDI Location Analyzer, which performs novel analysis using mobile phone GPS and census data. The study area included 10 target sites (urban parks and nature trails in the backcountry) located in the Sapporo metropolitan area in Japan. The survey period included snow-free seasons from 2019 to 2021, and 2019 was considered the period "before the pandemic." The results revealed that the number of visits during the pandemic increased compared with those before the pandemic, except for those of urban parks near the city center. In 2020, the proportion of repeat visitors increased for all 10 target sites. In addition, since the outbreak of the pandemic, distances between all urban parks and visitors' residences decreased. The same trend was observed for nature trails in the backcountry close to the city center. These findings indicate a generally decreasing trend in the number of visits to green spaces as many people have been refraining from visiting the site since the outbreak of the pandemic. Contrastingly, the number of visits by repeat visitors who reside close to the target sites has increased in some cases, which compensated for the general decreases.

1. Introduction

1.1. Research background

The COVID-19 crisis and its related policies have dramatically affected human life. As of January 2022, the total number of COVID-19 cases exceeded 346 million, resulting in over 5.5 million deaths worldwide (WHO, 2022). To prevent the spread of the disease, social distancing measures, including encouraging people to "stay-at-home," have been implemented worldwide. Additionally, some countries have restricted access to green spaces, including closing parks or allowing only limited use (Erdönmez and Atmiş, 2021; Freeman and Eykelbosh, 2020; Slater et al., 2020). As a result, daily exercise and movement, except where accessing food and health care is concerning, were

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significantly limited in many countries, including the UK and Australia. There is consensus that the recreational industry has suffered the most serious damages (Škare et al., 2021; Spennemann and Whitsed, 2021). However, during the period when such restrictions were relaxed or introduced, the importance of spending time in green spaces such as urban parks became more apparent (da Schio et al., 2021). Multiple studies have reported that these places are important for mitigating the negative psychological and physical effects of the COVID-19 pandemic as they provide space for outdoor activities (Geng et al., 2021; Rice and Pan, 2021). In recent studies, it was reported that people's engagement in recreational activities increased during the pandemic (Beery et al., 2021; Berdejo-Espinola et al., 2021; Grima et al., 2020; Ugolini et al., 2020) and they changed their recreational site of choice (e.g., Venter et al., 2020).

Quantifying changes in visitation structure, including the number of visitors and visits, plays a crucial role for management policies of green spaces, especially in the COVID-19 context (Kupfer et al., 2021). However, data and methodological limitations have led to conflicting results regarding the changes in the structure of visits to green spaces during the COVID-19 pandemic. For example, some studies showed an increase in visits to nearby recreational sites during the COVID-19 pandemic (Ugolini et al., 2020), whereas others showed an increase in visits to more distant recreational sites (Venter et al., 2020). This inconsistency can make it difficult to implement appropriate management. One of the reasons for conflicting results is the limitations of traditional approaches, as they are heavily dependent on the information available online or in self-reported data via surveys. Previous studies, for example, pointed out that the on-site sampling data procured via questionnaire surveys lacked samples of people who did not visit the site (i.e., zero visits) (Ward and Loomis, 1986). Another challenge in the traditional approach is the difficulty of capturing the effect of repeat visitors on the total number of visitors due to the survey period and cost. In the case that only repeat visitors who live nearby continued to visit the site and a large number of people refrained from visiting the green space due to the COVID-19 pandemic, the survey might capture only the increasing number of repeat visitors. Consequently, the result might be that the total number of visits increased, even if the actual total number of visitors and visits decreased. Additionally, the COVID-19 pandemic prevented researchers from conducting in-person surveys such as interviews and on-site questionnaire distribution (Lyu et al., 2021). Thus, it is difficult for the approach to identify the actual situation and the reason behind the change in recreational activities during the COVID-19 pandemic.

The use of Information and Communication Technology (ICT) proved advantageous in helping to understand the actual situation during the COVID-19 pandemic. Recent ICT developments provide high-volume data (i.e., big data) competitively and allow researchers and practitioners to monitor the visiting structure remotely with a high temporal and spatial resolution (Chen and Zhang, 2014; Donahue et al., 2018). As a tool to overcome the above-stated challenges, recreational studies have rapidly applied various types of ICT big data, specifically, social media and crowdsourced big data, mobile phone App based GPS data, and mobile phone network data (Ghermandi and Sinclair, 2019; Kolstoe and Cameron, 2017; Kubo et al., 2020). Evidence of green space use from ICT big data analysis is also abundant (e.g., Mears et al., 2021; Sinclair et al., 2022). Jaung and Carrasco (2020) indicate that mobile phone data plays an important role in robustly monitoring ecosystem services change in urban green space over time. Using mobile phone GPS data, Mears et al. (2021), for example, found that people spend an hour per week in green spaces. Furthermore, the applications of ICT technologies have rapidly increased during the COVID-19 pandemic (e.g., Cui et al., 2021; Sinclair et al., 2021; Venter et al., 2021). Cui et al. (2021), for example, showed that the COVID-19 pandemic made people spend more time in green spaces on weekdays than on weekends. Using GPS tracking data, Venter et al. (2021) found that recreational activity in urban green spaces increased during the lockdown period in Norway. However, these unique studies have primarily focused on the total number of visitors and/or visits, which is not sufficient information for management during and after the COVID-19 pandemic. Therefore, this study aimed to explore the changes in visiting behavior pertaining to green spaces, such as the number of visitors and visits to green spaces, considering the type of green spaces, before and after COVID-19. In particular, we attempted to answer the following questions using mobile phone location data in Sapporo, Japan:

- Has there been any change in the percentage of repeat visitors?
- What changes have occurred with respect to the distance between the green spaces and visitors' places of residence?

We believe our findings contribute to developing a management plan for urban parks and nature trails in the backcountry, which would be instrumental during the COVID-19 pandemic. Further, this study can also provide valuable insights into the role of ICT big data in monitoring green spaces in and around urban areas.

2. Method

2.1. Study area

Fig. 1 shows the study area, a place located in the Sapporo metropolitan area, which is one of the five largest metropolitan areas in Japan. The Sapporo metropolitan area includes Sapporo City and the adjacent areas of Otaru City, Ishikari City, Tobetsu Town, Ebetsu City, and Kitahiroshima City. The metropolitan area has a population of approximately 2.33 million (as of January 2021; Hokkaido Prefecture, 2021a). The Sapporo metropolitan area is located in the southwestern part of the Ishikari Plains in Hokkaido Prefecture, with mountainous terrain in the southwestern part. The eastern part is flat and hilly land, with residential areas and fields, as well as a vast lowland forest (Nopporo Forest Park). The northern part of the city, originally a wetland, has been developed as a residential area.

The original vegetation of the area is a cool-temperate forest characterized by deciduous broad-leaved trees, which are often covered with snow from early December to late March. Most of the nature trails in the backcountry are secondary forests, although some primeval types remain. It also contains artificial forests of *Larix kaempferi* and *Abies sachalinensis*, which are used for timber production but now strongly positioned as places that provide various ecosystem services, such as recreation. Some of the nature trails in the backcountry are also preserved as nature parks and natural monuments.

In this study, we selected 10 sites located in the Sapporo metropolitan area as the target sites (Fig. 1). The characteristics of each target site are summarized in Table 1. Based on a previous study (Kim et al., 2020), we selected urban parks to avoid bias in terms of area, main environment condition, and distance from the city center. Nakajima Park and Toyohira Park are urban parks whose surrounding land type is a garden. Both are closer to the city center than other urban parks. In contrast, Tsukisamu Park, Moerenuma Park, and Maeda Forest Park were selected as representative urban parks having a lawn setting. Among them, Tsukisamu Park is relatively closer to the city center as compared to other two urban parks and is surrounded by populated residential areas.

For nature trails in the backcountry, we selected recreational sites in surrounding towns and cities that are directly transferred to backcountry forests and mainly provide trekking trails (see Fig. 1). Nopporo Forest Park is not connected to backcountry forests, but the park is a vast forestland and the forests in the center of the park function like backcountry forests. Mt. Maruyama, Mt. Moiwa, and Mt. Sankakuyama have backcountry forests in the form of a peninsula, and are close to the city center, thus are easily accessible as compared to other nature trails in the backcountry. Mt. Teineyama and Nopporo Forest Park are far from the city center and each has a different type of land surrounding it. Mt. Teineyama is surrounded by a ski resort and a backcountry forest, while

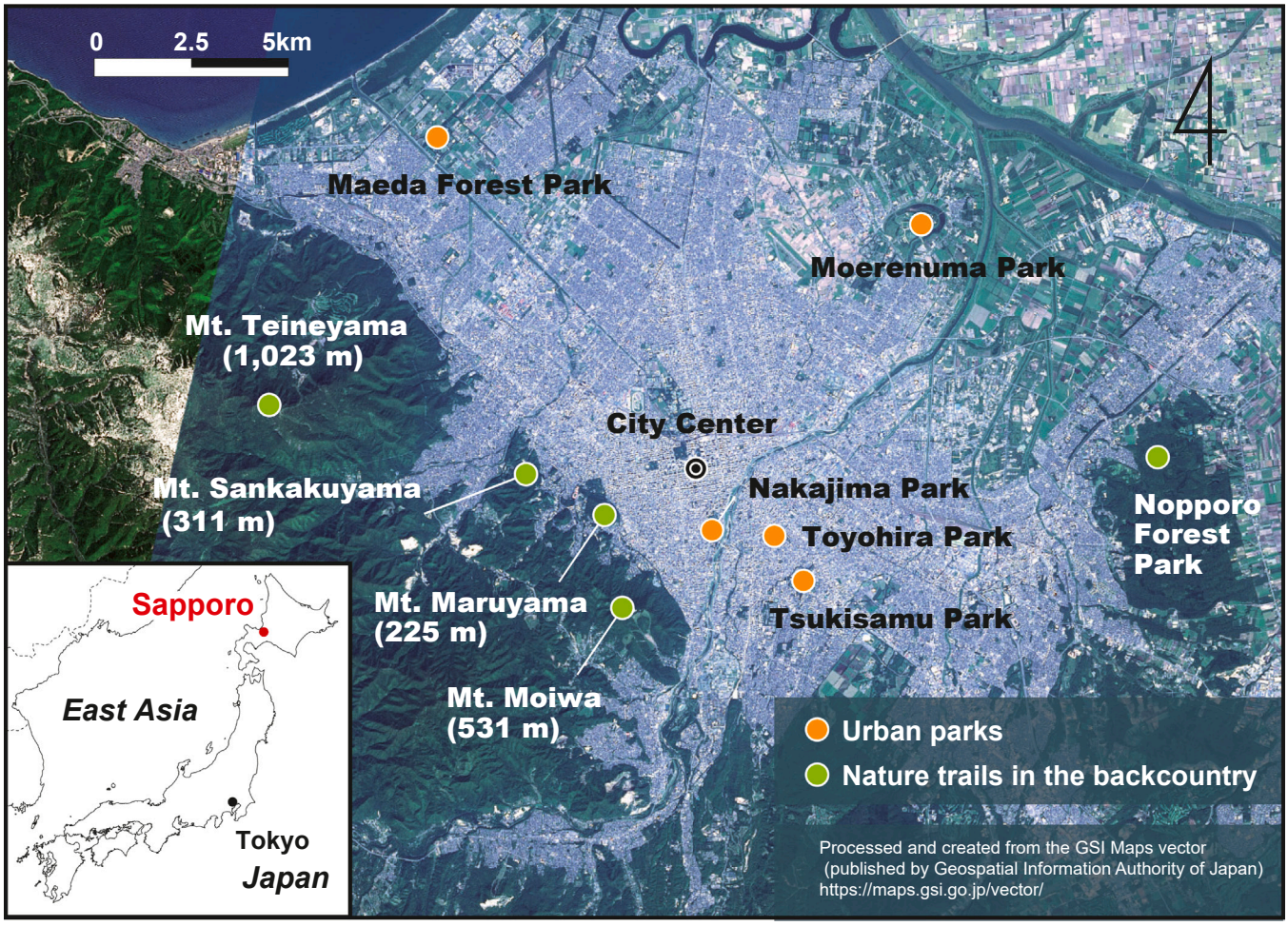

Fig. 1. Location of the Sapporo metropolitan area and target sites.

Table 1
Characteristics of target sites.

	Main environmental setting	Distance from city center (km)	Area (ha)/ Elevation (m)	Current status of surrounding land type
Urban parks				
Nakajima Park	Garden	1.6 km	24 ha	Commercial land, Residential area (mainly for condominium)
Toyohira Park	Garden	2.7 km	22 ha	Residential area
Tsukisamu Park	Lawn	4.0 km	7 ha	Residential area
Moerenuma Park	Lawn	9.2 km	104 ha	Farmland, Residential area
Maeda Forest Park	Lawn	12.4 km	60 ha	Farmland, Residential area
Nature trails in the backcountry				
Mt. Maruyama	Trekking trails	3.4 km	225 m	Residential area and backcountry forest
Mt. Moiwa	Trekking trails	4.7 km	531 m	Residential land and backcountry forest
Mt. Sankakuyama	Trekking trails	5.3 km	311 m	Residential land and backcountry forest
Mt. Teineyama	Trekking trails	13.2 km	1023 m	Ski resort and backcountry forest
Nopporo Forest Park	Trekking trails	14.1 km	Lowland forest	Farmland, Residential land

Nopporo Forest Park is surrounded by farmland and residential areas.

2.2. COVID-19 crisis measurement in Hokkaido Prefecture

Our study area, Sapporo metropolitan area, is a part of the Hokkaido Prefecture; approximately 45% of the population of Hokkaido Prefecture resides in the Sapporo metropolitan area (as of January 2021; Hokkaido Prefecture, 2021b). The measurement period of KDDI Location Analyzer (hereafter, KLA) and the spread of COVID-19 in Hokkaido Prefecture, including the Sapporo metropolitan area, is depicted in Fig. 2 (Hokkaido Open Data Portal, 2021). Approximately 62% of the cumulative number of new COVID-19 infections in Hokkaido Prefecture were reported to be residents of Sapporo City (as of November 30, 2021; City of Sapporo, 2021; Hokkaido Prefecture, 2021c). Sapporo was the city where the first COVID-19 case in Japan was detected, following which the governor of Hokkaido Prefecture declared a state of emergency in February 2020. Thereafter, the Japanese government declared a state of emergency across the country, which continued until May 2020. The state of emergency did not enforce any mandatory restrictions on going out, but it encouraged people to refrain from traveling across cities and towns. In Sapporo, the population density in the city center decreased by approximately 89% (Arimura et al., 2020). The spread of

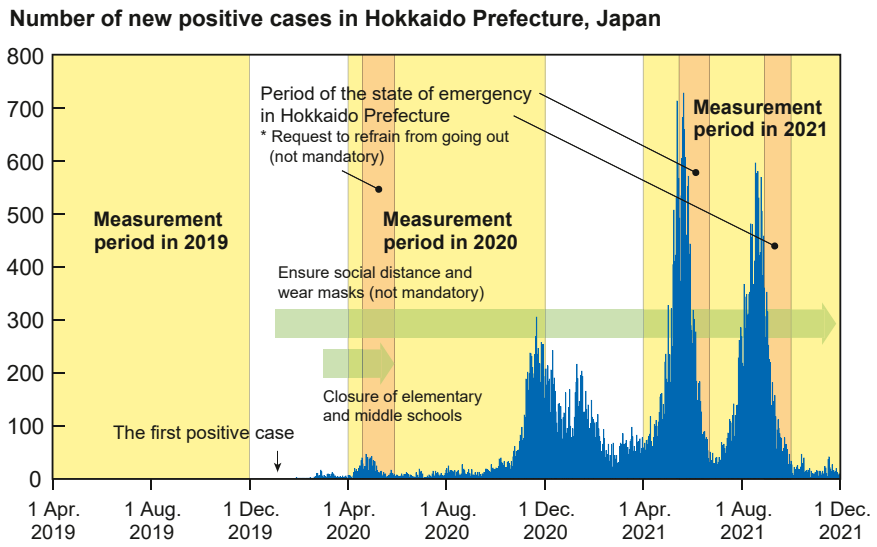

Fig. 2. Number of new COVID-19 infections in Sapporo city and measurement periods of KLA in the present study (Hokkaido Open Data Portal, 2021)

infection did not stop even in 2021, and the spread reached its peak twice. In 2021, the Japanese government declared a state of emergency twice in the Hokkaido Prefecture.

2.3. The situation of green space in and around the urban area during the COVID-19

This section shares information provided by local administrators, information that raised several points to be kept in mind when interpreting our results. During the period when the state of emergency was declared, some parking lots in green spaces (i.e., Moerenuma Park, Maeda Forest Park, and Tsukisamu Park) were closed, but the green spaces themselves remained open. Considering the evidence that some visitors access green spaces by car, it can be assumed that some of the visitors might have canceled their visit owing to the parking lot closure. In addition to the closed parking lots, the cancelation of events might have also affected the visits. For example, urban parks located in the city center (i.e., Nakajima Park and Toyohira Park) have facilities for hosting large-scale events (or facilities adjacent to parks). However, in 2020 and 2021, most large-scale events were cancelled in response to the Japanese government' a request not to hold them. The decrease in the number of visitors in 2020/2021 as compared to 2019 may be attributed to the decrease in the number of visitors associated with those events. The main visitors of some parks are tourists (e.g., Nakajima Park and Moerenuma Park). Since long-distance travel was discouraged to avoid the spread of COVID-19 during the pandemic, this likely influenced a decline in visitor numbers. The analysis of residence, especially the distance between each target site and visitors' places of residence, was greatly affected by this. For this reason, we focused the analysis only on local residents of the Sapporo metropolitan area, whose visitation to the green space was likely less affected by these restrictions.

2.4. KDDI Location Analyzer

The present study used KLA, a web application for estimating extrapolated populations based on census data and location data of smartphones, provided by KDDI CORPORATION and Giken Shoji International Co., Ltd. KDDI CORPORATION is the second largest carrier in the industry, with about 27.6% share of mobile phone contracts in Japan (Ministry of Internal Affairs & Communications, 2021). KLA is linked to Google Maps and the number of visitors and visits to the area (geo-fence) created on Google Maps can be estimated via the application. KLA anonymizes subscribers' location information and expands the information based on census data to estimate the extrapolated population in Japan. GPS location measurement subjects were KDDI smartphone owners aged over 20 years and who provided prior permission for the use of their GPS information. Foreign travelers were excluded.

The measurement period of data was three seasons from 2019 to 2021, with the 2019 data indicating the trend before the pandemic and 2020 and 2021 data indicating the trend after the COVID-19 outbreak. We focused on the visit behavior during the snow-free season (April to November). We set the measurement period consecutively from April to November.

2.5. Geo-fence

2.5.1. Geo-fence settings

We set up geo-fences in KLA as follows: for urban parks, geo-fences were set up at the boundary of the designated area. For nature trails in the backcountry where the summit is a destination, geo-fences were set up around the summit. In the case of Mt. Moiwa, a ropeway is directly connected to the summit, making the summit an urban sightseeing destination. The visitors usually use the ropeway for sightseeing and not for recreation in that area; therefore, we decided to exclude it from the measurement. Only the on-footers were considered and geo-fences were constructed on the trails on the west and east sides of the summit. The Nopporo Forest Park area was larger than the area in which the KLA geo-fence could be set up, so we set up the geo-fence in the northern part of the park that had maximum visitors. Hence, we could not ascertain the number of visitors and visits to Nopporo Forest Park. Finally, we excluded those who stayed within the geo-fences for less than 15 minutes as "passers-by" to distinguish between passers (e.g., commuters) and visitors. While interpreting the results, we accounted for information on the management of the geo-fence setting points (e.g., whether the sidewalks and/or trails were temporarily closed during the measurement period). Thus, we asked the local administrators to provide us the information pertaining to the management of geo-fence setting points.

2.5.2. Measurement of distance between each target site and visitors' places of residence

The mean value of the distance between each urban park and nature trail in the backcountry and visitors' places of residence was determined. As the distance is measured on a scale of wards in cities or municipalities in which the subjects reside, multiple data had the same value for the distances between the target site and visitors' places of

residence. Therefore, there is a possibility of bias regarding the mean and median if such a method is used for measurement. To mitigate the bias, we also measured the rate of change in the visits of visitors residing in the cities or municipalities that were close to the target site.

3. Results

3.1. Number of visitors and visits and proportion of repeat visitors

Table 2 shows the extrapolated population on a yearly and daily basis. Extrapolated population means the total number of visitors estimated to exist within the geo-fence where we set (i.e., 10 target sites), based on mobile location data and census data. "Unique visitor" is a term used in web analytics to refer to a person who visits a website at least once within the reporting period. Yearly unique visitors mean the sum of visitors that count as one even if they visit multiple times in the same year (from April to November). Thus, the value represents the number of visitors in eight months (from April to November). Daily unique visitors are the cumulative number of daily visitors over eight months. Thus, the value represents the number of visits in eight months. However, the number of visitors who visited multiple times in a day is counted as one.

Fig. 3 shows the changes in the number of visitors of the extrapolated population over 3 years for urban parks and nature trails in the backcountry. Using the 2019 value as a 100% reference value, the changes in the number of visitors in 2020 and 2021 are expressed as a percent. Overall, the number of visitors to urban parks decreased in 2020, and the tendency represented strongly the urban parks that were close to the city center such as Nakajima and Toyohira Parks. On the contrary, with respect to the nature trails in the backcountry, the number of visitors increased in 2020 at all nature trails regardless of their distance from the city center. In 2021, urban parks showed an increasing trend in all parks except Toyohira Park. On the other hand, nature trails in the backcountry all showed a decreasing trend and the number of visitors at some nature trails decreased more than in 2019.

Fig. 4 shows the changes in the number of visits of the extrapolated population over 3 years for urban parks and nature trails in the backcountry. The expression method of the graph is the same as Fig. 3. The number of visits in 2020 was similar to or increased in 2019 with the exception of two urban parks that where close to the city center (Nakajima and Toyohira Parks), and in 2021, the number of visits tended to increase in most parks. On the contrary, with respect to the nature trails in the backcountry, the number of visits increased at all nature trails in 2020. However, in 2021, the number of visits decreased for most nature trails, and the trend was strong for nature trails near the city center (i.e., , Mt.Maruyama and Mt. Moiwa). To sum up, urban parks and nature trails in the backcountry have exhibited different trends in the number of visitors and visits, with urban parks tending to recover or increase through a decrease, while nature trails in the backcountry, with the exception of some sites, maintain it through an increase.

Fig. 5 shows the changes in the proportion of repeat visitors. In the urban parks, the increase in the percentage of repeat visitors was observed in 2020 at all urban parks. In addition, the trend continued in 2021 for all sites,showing a tendency to remain high. On the other hand, the repeat visitors of many nature trails in the backcountry tended to increase in 2020 and then return in 2021, which is similar to the trend of change in the number of visitors and the number of visits.

3.2. Distance between the urban park/nature trail in the backcountry and visitors' places of residence

Table 3 shows the changes with respect to the distance between each urban park/nature trail in the backcountry and visitors' places of residence. As mentioned earlier, we narrowed down the target population to residents of Sapporo metropolitan area for estimation. This was done to avoid large mean values for distance in 2019, as they are likely to increase significantly after 2020 due to a decrease in the number of tourists from distant places. For example, 5808 visitors visited Moerenuma Park from residential areas more than 1000 km away in 2019, and the number reduced to 2826 visitors in 2020.

The trends in the mean distance of urban park and visitors' places of residence (the mean value of the linear distance to the place of residence defined by ward for Sapporo City and by municipality for the others) decreased in 2020 at all urban parks compared to 2019. This trend is continued in 2021 at most urban parks. Nakajima Park showed the largest decline, with a decrease of 14% in 2020 and 37% in 2021 compared to 2019.

Unlike urban parks, where mean distances tended to decrease overall, nature trails in the backcountry showed different trends depending on the nature trails. For nature trails in the backcountry, which are relatively close to the city center, the decrease in the mean distance was remarkably large. For example, Mt. Maruyama and Mt. Moiwa showed a decrease in mean distance in both 2020 and 2021, and both decreased further in 2021. On the other hand, the mean distance increased for a certain nature trail. Specifically, compared to 2019, the distance for Mt. Teineyama was found to have increased by 12% in 2020 and 23% in 2021. In sum, the trends in the mean distance between each

Table 2
Changes in number of visitors and visits to urban parks and natural trails in the backcountry.

	Extrapolated population[a]					
	Yearly unique visitors[b] (Number of visitors from April to November)			Daily unique visitors (The Number of visits from April to November)		
	2019	2020	2021	2019	2020	2021
Urban parks						
Nakajima Park	395,833	168,882	231,423	957,581	634,663	707,063
Toyohira Park	79,146	45,662	44,330	177,702	134,643	121,102
Tsukisamu Park	71,174	58,715	66,493	171,564	181,432	202,087
Moerenuma Park	133,180	94,114	100,410	190,928	192,412	200,774
Maeda Forest Park	69,498	62,134	74,796	182,436	215,535	242,709
Nature trails in the backcountry						
Mt. Maruyama	11,191	11,851	7234	15,993	20,862	11,672
Mt. Moiwa	17,074	18,483	11,570	29,322	39,063	28,554
Mt. Sankakuyama	6573	10,878	7811	14,338	27,117	17,647
Mt. Teineyama	1912	3505	1878	2147	5415	2143
Nopporo Forest Park	7496	9564	9226	17,583	25,981	31,204

[a] Since the extrapolated population was not calculated based on a sample survey, there exists no standard error. The accuracy verification conducted by the authors at facilities where the actual number of visitors is known indicated that the error did not exceed ± 20% in the range of values shown in this table. Therefore, the true value is at least within this range.

[b] Yearly unique visitors are the sum of visitors that count as one even if they visit multiple times in the same year (from April to November). Daily unique visitors are the cumulative number of daily visitors over eight months (from April to November).

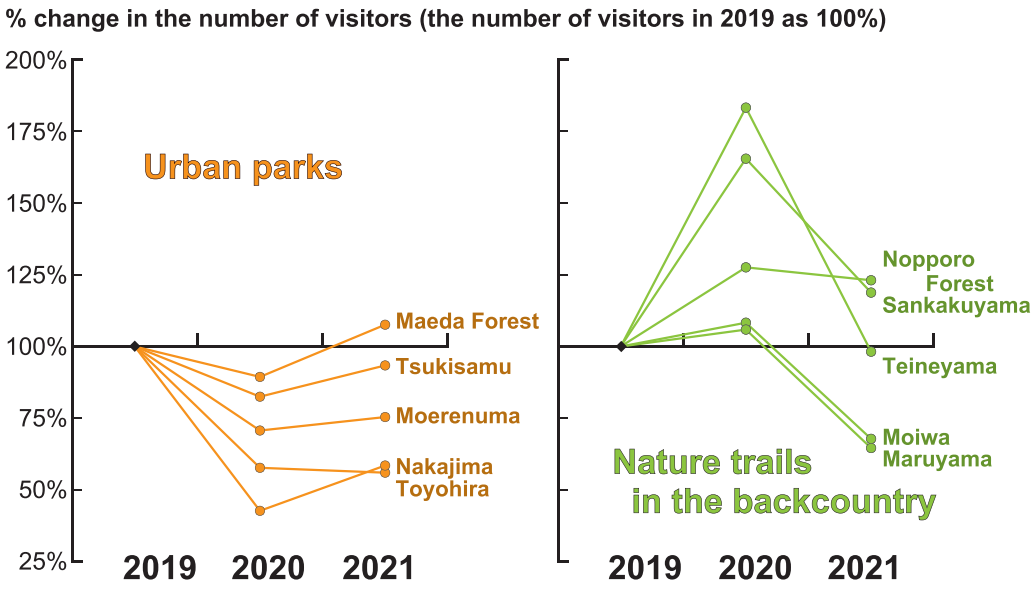

Fig. 3. Changes in number of visitors (taking the value in 2019 as 100%).

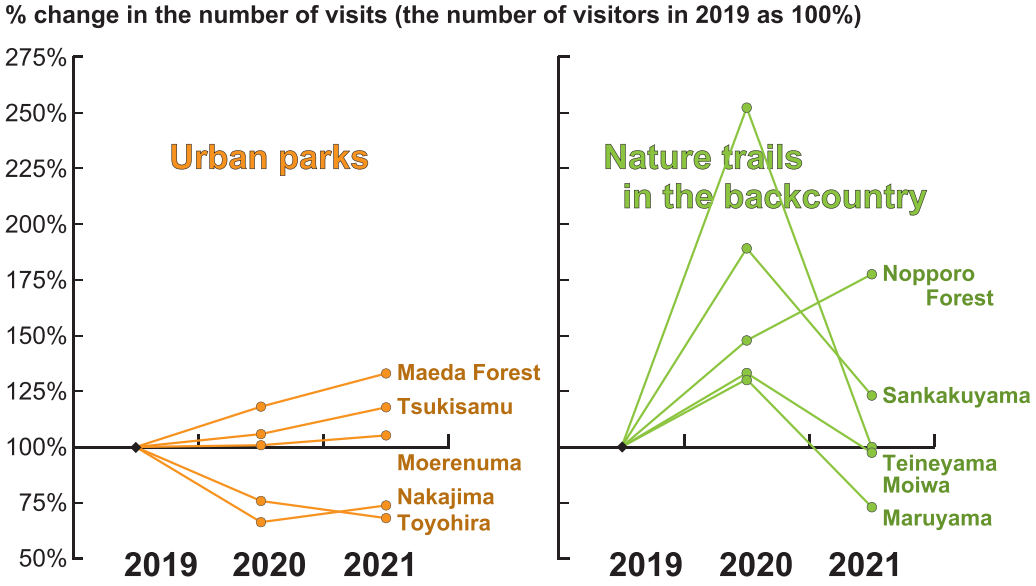

Fig. 4. Changes in number of visits (taking the value in 2019 as 100%).

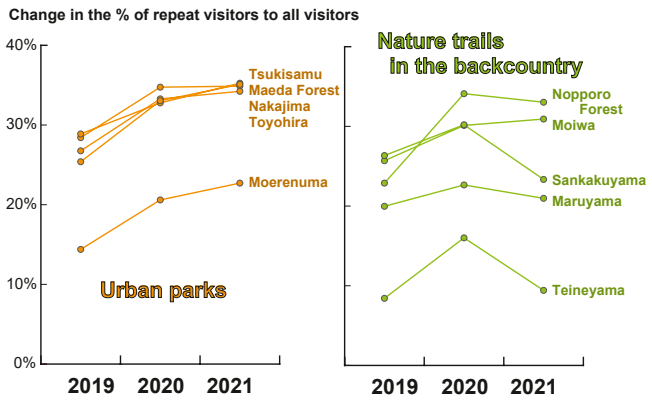

Fig. 5. Changes in the proportion of repeat visitors.

urban park/nature trail in the backcountry and visitors' places of residence differed depending on whether they were urban parks or nature trails in the backcountry.

3.3. Percentage of visitors from the nearest area of residence to each urban park/nature trail in the backcountry

The percentage of visitors from the nearest area of residence to each of the urban park/nature trail in the backcountry (areas defined by ward for Sapporo City and municipality for the others) is summarized in Fig. 6.

In the case of urban parks, the percentage of visitors from the nearest area of residence to urban parks increased at all parks in 2020. In 2021, this trend continued and showed a tendency to maintain a high level. In the case of nature trails in the backcountry, different trends were shown according to nature trails. In 2020, the number of visitors from the nearest areas of nature trails in the backcountry (Mt. Maruyama and Mt. Moiwa), located close to the city center, increased, but the remaining

Table 3
Mean distance between each urban park and nature trail in the backcountry and visitors' places of residence.

	Mean distance between the places of residence and the destination (Km)		
	2019	2020	2021
Urban parks			
Nakajima Park	7.8	6.7 (–14%)[a]	4.9 (–37%)
Toyohira Park	7.6	7.4 (–3%)	6.2 (–18%)
Tsukisamu Park	6.8	6.5 (–4%)	4.9 (–28%)
Moerenuma Park	9.6	9.0 (–6%)	6.5 (–32%)
Maeda Forest Park	11.0	10.6 (–4%)	10.6 (–4%)
Nature trails in the backcountry			
Mt. Maruyama	8.0	5.6 (–30%)	4.4 (–45%)
Mt. Moiwa	13.5	12.2 (–10%)	2.2 (–84%)
Mt. Sankakuyama	6.3	7.3 (+16%)	6.4 (+2%)
Mt. Teineyama	12.0	13.4 (+12%)	14.7 (+23%)
Nopporo Forest Park	6.3	6.5 (+3%)	5.5 (–13%)

[a] The parentheses indicate the rate of change for 2020 and 2021 when 2019 values represent 100%.

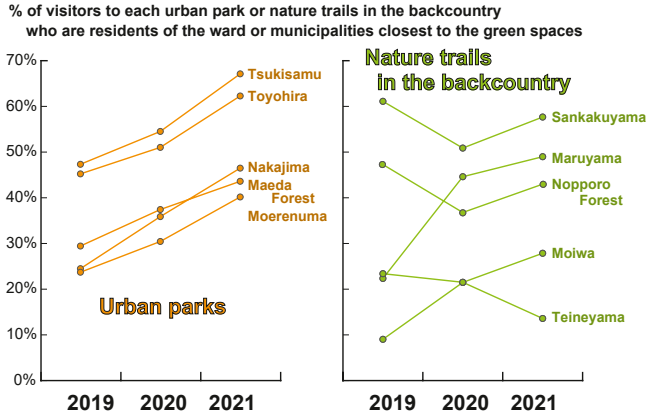

Fig. 6. Percentage of visitors from the nearest area of residence to each urban park and nature trail in the backcountry.

nature trails showed a decrease. In 2021, all trails with the exception of Mt. Teineyama tended to recover from their 2020 decline or to increase further.

4. Discussion

4.1. Structure leading to changes in the number of visitors and visits

The results in Figs. 3 and 4 suggest that there was a decrease in the number of visitors and visits to urban parks in the Sapporo metropolitan area after the spread of COVID-19. These results may be attributed to the fact that many people stayed home. Using big data, Arimura et al. (2020) found that people in the Sapporo metropolitan area stayed at home and refrained from going out to the city center following government's recommendations. Lopez et al. (2020) also reported that people were concerned about congestion and the inability to maintain a social distance when visiting urban parks after the COVID-19 outbreak. Meanwhile, managers of some urban parks might not acknowledge that the number of visits had decreased because decrease in the number of visits was not significant, as shown in Fig. 4. This may be because some visitors became repeat visitors and the existing visitors living near the urban parks had increased their number of visits, as shown in Figs. 5 and 6.

As also shown in Figs. 3 and 4, the number of visitors and visits to the nature trails in the backcountry in the Sapporo metropolitan area increased, except for those of some sites. Previous studies have indicated that new visitors came for nature trails in the backcountry or chose tracks and trails far away from their residences (Derks et al., 2020; Espiner et al., 2022; Grima et al., 2020). In addition, the increase of visitors was larger for nature trails in the backcountry far from the city center, which is also consistent with the results of previous studies. For example, Venter et al. (2020) reported a positive association between the increase in recreational activities and remoteness of the trail. In our study, repeat visitors living near urban parks contributed to the increase in the number of visits. No such trends were observed in nature trails in the backcountry except for those sites that were close to the city center. On the other hand, the results of nature trails in the backcountry indicated a feature not found in urban parks: the number of visitors and visits increased in 2020 but decreased in 2021 (Figs. 3 and 4).

The mean distance between visitors' places of residence and nature trails in the backcountry did not decrease (Table 3), and the percentage of visits from the nearest place of residence showed no clear changes in the trend (Fig. 6). Similar changes could be observed with respect to the nature trails in the backcountry near the city center, like in some urban parks (the mean distance between the site and visitors' places of residence decreased and the percentage of visits from the nearest area of residence increased). Among nature trails in the backcountry, Mt. Maruyama and Mt. Moiwa, which are close to the city center and easily accessible, were destinations of hiking for kindergarten and elementary school students before COVID-19. They were visited by children and accompanying adults from a wide section of the Sapporo metropolitan area. However, during the COVID-19 pandemic, most of these hiking events were cancelled. The decrease in mean distance is likely due (partially) to these changes in visitors, rather than simply to an increase in visits from the nearest area of residence.

Regarding the result of decreased numbers of visitors and visits in 2021, we considered the possibility of a complementary relation between urban parks and nature trails in the backcountry with different trends. As shown in Figs. 3 and 4, the number of visitors and visits to nature trails in the backcountry increased significantly in 2020 and decreased significantly in 2021, whereas the number of visitors and visits to urban parks showed the opposite trend, albeit to a lesser degree. When people are concerned about congestion and their inability to maintain social distance when visiting urban parks (Lopez et al., 2020), they may temporarily shift their visits to nature trails in the backcountry, where the number of visits is relatively low and the risk of infection is assumed to be low as well (Ferguson et al., 2022). Meanwhile, although the number of new infections increased in 2021, the understanding of COVID-19 had deepened, which could explain why people began to visit urban parks again.

Nonetheless, we observed a large difference in the number of visits to urban parks and nature trails in the backcountry (Table 2). Therefore, much of the decline in the number of visits to urban parks may not be primarily owing to the shift in visits to nature trails in the backcountry, but rather to people staying home. Interpretations of these complementary relations are only inferences based on the results obtained. The data obtained in this study cannot directly indicate whether people shifted their visits from urban parks to nature trails in the backcountry or vice versa.

4.2. Importance of quantitative research

Quantitative research plays an important role in understanding a situation. First, the quantitative presentation of actual changes facilitates a better understanding of the current situation and the swift response of the government. Based on our results indicated in Table 2, a decrease in the number of visitors to the five urban parks was observed both in 2020 and 2021 as compared to 2019. It has been recognized that visits to urban parks contribute to the maintenance of mental and physical health (Kaczynski and Henderson, 2007; McCormack et al., 2010; Tyrväinen et al., 2014; Ward Thompson et al., 2012). Therefore, the decreased visitors indicate that a public health challenge may arise. In addition, spatial disparity of urban parks has been a major challenge

(e.g., Lee and Hong, 2013; Wüstemann et al., 2017; Xu et al., 2017), that is more likely to affect older adults with limited physical mobility (Guo et al., 2019). In the context of our study, the spatial disparity may also have been magnified due to highly contagious COVID-19.

Second, relying solely on on-site or self-reported data may misrepresent the actual situation because of the limited sample. When discussing the increase or decrease in the number of visitors and visits, the focus should be on changes in an area as a whole rather than on changes in each urban park or nature trail in the backcountry. In this respect, the quantitative approach adopted in this study, or a survey based on on-site or self-reported survey, seems to have advantages. If we grasped the changes in the number of visitors and visits based on on-site or self-reported data, as done in studies that reported a significant increase or decrease in the number of visitors to green spaces (Addas and Maghrabi, 2022; Venter et al., 2020), we would have drawn the wrong conclusions. For example, in some urban parks, the number of visits did not actually decrease significantly (Fig. 4)—managers could understand the results to mean that the number of visitors had not decreased. However, if they interpreted the results carefully, they would realize the possibility that the number of visitors had decreased while the number of repeat visitors had increased, supplementing the number of visits.

Moreover, relevant to urban parks and nature trails in the backcountry in the Sapporo metropolitan area, reports have indicated the twin occurrence of the trend of more visits to nearby recreational sites (Ugolini et al., 2020) and that of more visits to more distant recreational sites (Venter et al., 2020). In other words, changes in the number of visitors and visits owing to the COVID-19 pandemic either increased or decreased, depending on whether the target was an urban park or a nature trail in the backcountry, and whether it was near the city center or not. Changes in the number of visitors and visits may also be related to each across site, as discussed in the complementary relation in Section 4.1.

4.3. Management implications

Our results quantitatively showed the changes in the number of visitors and visits, and can be used for the management of green spaces from various perspectives.

As shown in the previous section, some individuals became repeat visitors along with increased visits from the existing visitors living near urban parks. Changes in these types of visitors may affect management policies and facility planning of urban parks. Addas and Maghrabi (2022) indicate that, the COVID-19 pandemic had a substantial impact on the use attitudes and perceptions of urban parks, in comparison with non-pandemic periods. Therefore, the services demanded and place attachment of new repeat visitors, may differ from those of previous visitors. In such cases, management policies may need to be reviewed. Moreover, if visitors are replaced by people who live nearby, there may be more empty parking spaces. In this case, the existing parking spaces will be excessive, and facility planning may need to be reconsidered.

The increase in the number of visitors and visits to nature trails in the backcountry in some sites is smaller than those for urban parks (Table 2), but the percentage increase is quite large (Figs. 3 and 4). Nature trails in the backcountry, which have inherent wilderness areas, are not provided by urban parks, but they present a variety of recreational opportunities (Clark and Stankey, 1979; Gundersen et al., 2015). For this reason, the existing visitors, especially those who expect a quiet and uncrowded recreational experience, might be concerned about the qualitative changes in the recreation settings (Andereck and Knopf, 2007). Therefore, it is necessary for the park managers to identify the increase or decrease in the number of visits to nature trails in remote areas through continuous monitoring.

5. Limitations and future research

There are some limitations to the method used in this study. Here, we used the extrapolated population estimated by KLA as data. Estimated extrapolated population is unique in that it avoids selection bias, which is a problem with device-generated data. Big data can be categorized into user-generated, device-generated, and transaction data in terms of source (Li et al., 2018). Device-generated data can be further divided into call data records, GPS location data, Bluetooth data, and opt-in application data (Grantz et al., 2020). KLA applied in this study used GPS location data. The selection bias in device-generated data is due to the share of carrier subscriptions, device ownership by age, and unfamiliarity with application operations (when using opt-in applications). Such selection bias is corrected in the KLA estimation process, which includes the expansion of information based on census data. However, KLA is not without issues. First, KLA yields extrapolated populations as aggregate values (point estimates), therefore statistical tests could not be applied. Statistical tests require information on each smartphone owner, but individual data are not disclosed for privacy protection reasons. Second, the details of the estimation algorithm of the extrapolated population are not released.

As a future research, we propose the following points. In this study, due to the limitation of measurement range, the visitor's residences were investigated on the ward or municipalities' level, but few studies have explored visitors' use of green spaces by narrowing the range of their residences. Further investigation concerning the range of visitors' residences is needed to understand fully visitors' green space use behavior considering COVID-19 effects. While this study used KLA to explore visitors' residences on a wide scale, future research needs to narrow down the range of residence and review the structure leading to changes in number of visitors and visits. In addition, the three-year trend results obtained in this study can be utilized in the short-term management aspect, but may not be appropriate for use in the long-term because these trends are subject to change. Therefore, additional monitoring of fluctuation trends is required for long-term management.

6. Conclusion

This study explores the quantitative changes in the number of visitors and visits according to the types of green spaces before and after the COVID-19 outbreak. For a better understanding of the quantitative changes in the number of visitors and visits, we explored the change in the proportion of the repeat visitors and change in the distance between the green spaces and visitors' places of residence. To understand these challenges, we used KDDI Location Analyzer, which estimates extrapolated populations based on location data of smartphones and census data. The extrapolated population is an estimate of the number of visitors who would have actually visited or visits that would have actually occurred.

The results showed that changes in the number of visitors and visits due to the COVID-19 pandemic can increase or decrease depending on whether it is an urban park or a nature trail in the backcountry, and depending on the distance from the city center. This study also explored the structure that caused this change, and found that repeat visitors and visitors from nearby areas from each target site contributed to the increase in the number of visits to urban parks and nature trails in the backcountry. These findings are difficult to clarify based on the information obtained through on-site or self-reported data. These findings can be used as a reference in management planning for urban green spaces in the era of the COVID-19 pandemic.

CRediT authorship contribution statement

Hyerin Kim: Visualization, Resources, Writing – original draft, Writing – review & editing, Visualization. **Yasushi Shoji:** Conceptualization, Formal analysis, Funding acquisition, Methodology, Writing - original draft, Writing - review & editing. **Kota Mameno:** Methodology, Formal analysis, Investigation, Resources. **Takahiro Kubo:** Conceptualization, Methodology, Resources, Funding acquisition. **Tetsuya**

Aikoh: Conceptualization, Methodology, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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