Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
An integrated approach to monitoring and estimating COVID-19 risk exposure among leisure-time physical activity participants

Ingrid E. Schneider a, *, Greg Lindsey a, Michael Petesch b, Christopher J. Wynveen c, Megha Budruk d, Bill Hendricks e, Heather Gibson f, Kim Shinew g, Taylor Stein f, Deonne VanderWoude h

a University of Minnesota, USA
b Minnesota Department of Transportation, USA
c Baylor University, USA
d Arizona State University, USA
e Cal Poly, USA
f University of Florida, USA
g University of Illinois, USA
h City of Boulder, USA

ARTICLE INFO

Keywords:
Public health
Daily traffic
Risk
Density

ABSTRACT

Background: Leisure time physical activity (LTPA) provides both health benefits and risks, particularly during a pandemic. During the COVID-19 pandemic, significant increases in close-to-home LTPA raised concerns for public health and land managers alike. This project illustrates a novel, integrated monitoring approach to estimating COVID-19 risk exposure during trail-related LTPA, with implications for other public spaces.

Methods: COVID-19 risk exposure was conservatively calculated from the integration of in-person observations of LTPA trail groups and automated monitoring of trail traffic volumes in spring 2020. Trained observers tracked 1,477 groups. Traffic volume estimates and observed distance data were integrated, considering occlusion and total trail traffic volume.

Results: 70% of groups had one or more encounters. Among individual users, 38.5% were 100% compliant across all events observed but 32.7% were not compliant. Considering trail traffic volumes and annual daily traffic volume, exposure to risk of COVID-19 was conservatively estimated at 61.5% among individual trail users.

Conclusions: Monitoring opportunities and challenges of health risk exposure exist. Adjusted exposure measures based on volume counts can approximate numbers of unique individuals exposed, inform management actions, efficacy and policy decisions.

1. Introduction

As coronavirus-19 disease emerged, indoor exercise facilities closed and people took to public areas for physical activity.

* Corresponding author. 115 Green Hall, 1530 Cleveland Ave North, St Paul, MN, 55108, USA.
E-mail addresses: ingrids@umn.edu (I.E. Schneider), linds301@umn.edu (G. Lindsey), michael.petesch@state.mn.us (M. Petesch), chris.wynveen@baylor.edu (C.J. Wynveen), Megha.Budruk@asu.edu (M. Budruk), hendric@calpoly.edu (B. Hendricks), hgibson@hhp.ufl.edu (H. Gibson), shinew@illinois.edu (K. Shinew), tstein@ufl.edu (T. Stein), vanderwouded@bouldercolorado.gov (D. VanderWoude).

https://doi.org/10.1016/j.jth.2021.101088
Received 17 February 2021; Received in revised form 17 April 2021; Accepted 13 May 2021
Available online 19 May 2021
2214-1405/© 2021 Elsevier Ltd. All rights reserved.
Subsequently, close to home leisure-time physical activity (LTPA) surged, leading to both opportunities and challenges. The opportunity to remain active and reduce stress throughout the pandemic was heralded and clearly categorized public parks and green spaces as ‘critical infrastructure’ during pandemic periods (Derks et al., 2020; Lopez et al., 2020) and called for their increased attention and development to improve public health (South et al., 2020). However, the challenge of providing safe physical activity on public lands emerged, leading to behavioral warnings, park closures, carrying capacities, and recommendations. Physical distancing has remained an important element of safe behaviors in all settings. As of spring 2021, the U.S. Center for Disease Control’s (CDC) recommends people maintain a minimum six-foot distance from others even when outdoors (CDC, 2021). The reality of compliance to this recommendation remains unknown. Despite the availability of relatively low-cost sensors and calls to increase monitoring to augment field observations (English and Bowker, 2018; Jones et al., 2018; Snider et al., 2018; Ziesler and Pettebone, 2018), automated facility monitoring is not standard practice. Further, most existing monitoring devices do not measure distances between users. The emergence, scope, and severity of the COVID-19 pandemic underscores the importance of such monitoring, including field observations.

We illustrate a novel, integrated approach to monitor CDC distancing guideline compliance and estimate potential risk exposure on multiple-use trails. From a transportation perspective, exposure may be defined as a measure of the number of potential opportunities for an event such as a crash or, in this case, spread of a virus, to occur (FHWA, 2018). This measure has been quantified in multiple ways. Here, we use counts of pedestrians and bicyclists. Risk, in the transportation context, is a measure of the probability of an event given exposure (FHWA, 2018) and, in the health literature, the probability that something will cause injury or harm (Agency for Toxic Substances and Disease Registry, 2021). Risk factors are any attributes or characteristics that affect the likelihood of a safety outcome (FHWA, 2018). Hence, in our case, we estimate exposure and compliance with social distancing guidelines, one of the multiple risk factors associated with the potential for contracting the COVID-19. Our objectives were to (1) integrate data to document the proportion of groups and individuals within groups that complied with the CDC physical distancing guidelines and subsequently estimate COVID 19 risk exposure, and (2) summarize challenges in estimating numbers of individuals potentially at risk, even when use estimates are available, (3) highlight opportunities to inform planning and policy.

2. Methods

2.1. Study location: The Sather Trail

The study site was selected both out of convenience and its status as both a local and regional draw within the Twin Cities of Minneapolis and St Paul, Minnesota. In 2019, the White Bear Lake community (population 25,875; US Census Quick Facts 2019) was predominantly composed of those who identify as white (89.4%). The remainder identify as Asian (4.4%), Hispanic or Latinx (3.7%), or Black/African Americans (2.5%). More than half of the White Bear Lake residents identified as female (52%). About one-fifth of the population was under 18 years of age or over 65 years (21.0% and 19.8%, respectively). For context, Minnesota’s state trail users typically identify more frequently as white than the state population, are 45 years or older and evenly split by gender (MN DNR 2020). Similarly, metro-area trail visitors most frequently identify as Caucasian, are between ages 37 and 56 and evenly split by gender (Metropolitan Council 2016).

The Mark Sather Trail connects other trails as part of a larger 34-mile regional trail system and is anchored by two beach areas. The 10-foot wide trail is situated 1.5 miles along White Bear Lake, hosting those who bike, walk, stroll and otherwise enjoy the leisure time activities it affords (https://www.whitebearlake.org/sites/default/files/fileattachments/parks_and_recreation/page/7561/lake_links_trail_master_plan.pdf). Observers could safely observe trail visitors from a distance and get access to the trail even while governmental travel restrictions were in place.

Minnesota’s first confirmed COVID-19 case occurred in the county housing our study site on March 6, 2020. The number of new COVID cases ranged from 7 to 181 throughout our observation period with case rates at 6.4% per 10,000 residents reported in June (Ramsey County 2020).

2.2. Monitoring protocols

Methods included both trail user group behavior observations and automated trail traffic monitoring. These data were integrated to estimate exposure to COVID-19 risk on the trail. Methods were based on guidelines for distancing published by Minnesota’s Governor on March 13, 2020 mirroring the U.S. Center for Disease Control recommendations (MDH 2020).

2.2.1. Physical distancing observation protocol

Observation protocols included selection of an observation zone and procedures for identifying, tracking, and determining trail user group distancing compliance. Following a systematic observation tool that was pretested and refined, trained observers unobtrusively viewed visitor groups within a 480 foot ‘observation zone.’ A group was defined as one or more individuals traveling on the trail together. An event was defined as when a group being tracked (Group A) encountered or interacted with another group (Group B) on the trail (e.g., passed a group from the oncoming direction). Trained observers identified group size, activity and distance between any encounters, among other variables. Groups where all members were six feet or more apart were considered compliant. Distance estimation was practiced during training using small marker flags to help observers gauge distances.

Observations occurred throughout the day (sunrise to 9:59 a.m., 10 to 1:59 p.m., 2 to 5:59 p.m., and 6 p.m. to sunset) and throughout the week. Typically observation sessions lasted between one to 2 h to maximize reliability (Rowley 1978) and minimize observer fatigue. Field observations of social distancing behaviors were conducted in 48, 1–2-h sessions between March 31 and June
2.2.2. Trail traffic monitoring protocol

The Minnesota Department of Transportation (MnDOT) followed standard agency protocols when monitoring and validating trail traffic volumes (Minge et al., 2017; FHWA, 2013) and supplemented them with additional video validation. Steps included counter deployment, use of video recordings to determine rates of occlusion and count adjustment factors, and use of day-of-year factoring methods to estimate traffic volumes on days when counters were not deployed. MnDOT deployed automated infrared and pneumatic tube counters from May 12 through June 14 to obtain trail traffic volume estimates.

When deployed on trails, automated counters systematically undercount both pedestrians and cyclists because the infrared sensors and pneumatic tubes, respectively, may be unable to differentiate users passing simultaneously (Proulx et al., 2016; Minge et al., 2017). This problem, known as occlusion, typically is greater for pedestrians than cyclists because pedestrians are more likely to travel beside one another and because the pneumatic tubes, which are used for bicycle counts, are less susceptible to this type of error. To adjust counts for occlusion, researchers video recorded 4.75 h of traffic (23 15-min blocks), counted 1,556 trail users, and compared counts from the video to sensor readings (Table 1). Mean error rates (i.e., undercounts) for pedestrians and bicyclists were, respectively, 22% and 12%, resulting in adjustment factors of 0.78 and 0.88, used, respectively, to inflate all pedestrian and bicycle traffic volumes from sensors.

Trail traffic volumes for the periods January 1-May 11 and June 15-June 30 were estimated from the May 12-June 14 counts with the day-of-year factoring method used by MnDOT and other agencies to estimate annual average daily traffic (AADT) from short duration samples. This method, which assumes that pedestrian and bicycle traffic on similar types of facilities in nearby areas increase and decrease similarly in response to changes in weather, produces the most valid AADT estimates (El Esawey 2016; Hankey et al., 2014; Nosal 2014).

3. Results

3.1. Compliance with physical distancing guidelines

Of the 1,477 tracked groups, 69.9% had one or more encounters with another party, equaling 2,091 total events (Table 2). For groups with encounters, the mean number was two. Groups were compliant with physical distancing guidelines in 42.8% of these events. Among groups with events, 45.6% were compliant with the CDC physical distancing guidelines across all events, while 28.1% sometimes were compliant, and 26.1% never compliant.

To estimate exposure to risk, individual data were extracted from group data. The groups included 2,324 different users, an average of 1.6 persons/group (Table 2). Slightly more than 72% of individuals experienced events while observed. Only 38.5% of users were compliant in all their events; 28.8% sometimes were compliant, and nearly one-third (32.7%) were never compliant. Given observations were conducted only on one portion of the trail and a visitor’s experience, we extrapolated our data to create a conservative estimate of total risk exposure. Assuming (1) the 28% of individuals who did not experience events in the observation zone experienced events at other times during their visit to the trail and (2) their rates of compliance were the same as those observed with events in the observation zone, then it seems likely, at minimum, 61.5% of all users have potential COVID-19 exposure risk one or more times. This estimate is a minimum because users who were 100% compliant in the observation zone could be non-compliant later.

3.2. Trail traffic volumes

Trail traffic volumes, as noted, are extrapolations of monitoring results (Fig. 1A) using day-of-year factors derived from another comparable suburban trail in the metropolitan area with a permanent counter. Total estimated trail traffic flow through the observation zone between January 1, 2020 and June 30, 2020 was 150,758; 90% (135,171) occurred between March 13 and June 30 when physical distancing guidelines were in effect (Fig. 1B). The mean daily traffic volume between January 1 and June 30 was 828. During the spring and summer when physical distancing guidelines have been in effect, the mean daily traffic volume was 1,229, and the maximum and minimum daily traffic totals were 2,822 and 71, respectively. We realize these numbers for spring may be unusually high due to the pandemic situation. However, it is precisely this high use that is driving the interest in the analysis.

3.3. Data integration

Integration of field observations with traffic counts and flows for the same time periods provides insight into factors associated with physical distancing guideline compliance. Between May 12 and June 14 when automatic traffic counters were deployed, observers

| Table 1 |
| --- | --- | --- |
| Adjustment factors to correct for occlusion. |  |
|  | Pedestrians | Bicyclists | Total |
| Counter | 418 | 216 | 1,268 |
| Video | 533 | 245 | 1,556 |
| Counter/Video | 0.78 | 0.88 | 0.81 |
completed 18 observation sessions that averaged 1.4 h in duration. During these sessions, observers tracked 506 groups that included 791 trail users, an average of 1.6 persons per group. Approximately 68% of groups had events during this period; a total of 679 events was observed. The event compliance rate for this subset of the data was 56.4%, 13.6% higher than the group compliance rate for all sampling sessions. Among people with events, only 38.4% were 100% compliant across all events; the comparable percentage for all observations was 38.5%.

Subset data analysis reveals (1) the event compliance rate for groups is inversely correlated with the mean number of people in a group (Fig. 2) and the percentage of individuals who were 100% compliant across events is inversely correlated with the trail traffic flow (users/hour) during the sample observation (Fig. 3). Both mean size of user group and hourly traffic flow are indicators of potential congestion.

---

**Table 2**

| Measure | Groups | Individual Users |
|---------|--------|------------------|
|         | Sample Size | Percent | Sample Size | Percent |
| Total tracked | 1,477 | 100 | 2,324 | 100 |
| With events | 1,033 | 69.9 | 1,678 | 72.2 |
| No events | 444 | 30.1 | 646 | 27.8 |
| Total events | 2,091 | 100 | | |
| CDC 6 foot + Distant Compliant events | 894 | 42.8 | | |
| Non-Compliant (less than 6 feet) | 1,195 | 57.1 | | |

| Measure | Groups | Individual Users |
|---------|--------|------------------|
|         | Sample Size | Percent | Sample Size | Percent |
| Always compliant (100%) | 471 | 45.6 | 646 | 38.5 |
| Sometimes Complaint (1-<100%) | 290 | 28.1 | 483 | 28.8 |
| Never compliant (0%) | 272 | 26.3 | 549 | 32.7 |

---

**Fig. 1.** a) Measured daily trail traffic, Mark Sather trail May 12 to June 14, 2020. b) Estimated daily trail traffic, Mark Sather trail January 1 to June 30, 2020.

---

**Fig. 2.** Correlation between group size and group compliance rate, Mark Sather trail January 1 to June 30, 2020 (n = 18).
4. Discussion and implications

Integrated LTPA group data and trail traffic volume revealed a lack of physical distancing among more than half of the observed and subsequent exposure to risk from COVID-19. Further, given compliance decreases with group user size and hourly traffic flow, it is likely that compliance rates on urban trails with similar geometry (e.g., trail width) but greater use (i.e., higher hourly traffic flows) will be lower. The implications are that the majority of individuals who choose to visit multi-use trails will experience one or more encounters and potential risk exposure. For vulnerable groups such as those over 65 or with health risks, this exposure is even more significant than the general population and should be accounted for in future monitoring efforts.

This novel approach informs the balance of risk and benefits related to planning for and policy related leisure time physical activity during public health crises. The integration of relatively easy and safe data to collect can inform the efficacy of existing and changed management practices, such as employing messaging to increase physical distancing. Efforts to encourage physical distancing are akin to efforts to encourage socially-beneficial behaviors such as cyclists warning pedestrians they are passing from behind and obeying traffic signals at trail-roadway intersections. For example, Deslatte (2020) observed that consistent messages concerning social distancing as a public health matter were more effective than messages framing social distancing as an economic issue and messages delivered by known government officials were more effective than those delivered by an unknown expert. Applications of lessons learned from these initiatives will be useful to assess efforts to foster physical distancing. Beyond messaging, additional consideration of activity type and exposure duration will be useful to refine these estimates as the science evolves (Eisenstein, 2021).

While these results provide valid estimates of trail user compliance with physical distancing guidelines and of daily traffic volumes, they do not enable estimation of the number of unique individuals who use the trail and either follow distancing guidelines or participate in events associated with potential exposure. We illustrate this point and the challenges of determining the number of unique individuals who might experience exposure to risk with an example using data from June 2020, the month with the greatest estimated traffic flows (42,085) and simple scenario analysis (Table 3). Many if not most people who use suburban trails like the Sather Trail start from a point, make an out-and-back trip, and return to the point of origin. This pattern of use means they may be counted twice if they pass by an automated sensor like those used in this study. For example, in a recent intercept survey conducted by the Minnesota Department of Natural Resources, 85% of trail users reported taking out-and-back trips (MDNR 2020). Similarly, based on internal data, managers of the count program for the Little Miami State Park Trail in suburban Cincinnati estimated 95% of users make out-and-back trips and that the remaining five percent of trips were taken by individuals who enter and exit at different locations (Theuring 2016). They therefore estimate total unique visits as 52.5% of total traffic counts (i.e., 5% + 95%/2 = 52.5%). Assuming similar patterns of use occur on the Sather Trail, which is likely because of its short length, trail traffic counts here are much higher than numbers of visits. We do not know the number of visits reflected in the traffic counts, but we can illustrate ranges with scenario analyses. If we assume that between 75% and 95% of user visits involve out-and-back trips, the number of visits to the Sather Trail in June ranged from 22,000 to 23,600 (Table 3).

We next need to account for multiple trips during a month by the same individual. June has 4.3 weeks. Evidence from surveys on suburban trails suggests trail users visit trails multiple times per week. For example, in an intercept survey conducted for the Mid-Ohio Regional Planning Commission, two-thirds of respondents said they visited trails three or more times in the prior seven days; the

| Table 3 | Estimates of unique visitors and compliance rates in June under different assumptions. |
|---------|--------------------------------------------------------------------------------------|
| June traffic count | 42,085 |
| % Users Making Out & Back Trips | 95 | 85 | 75 |
| Estimate of monthly visits | 22,095 | 23,147 | 26,303 |
| Weekly Visits | 1 | 3 | 5 | 1 | 3 | 5 | 1 | 3 | 5 |
| Monthly Visits | 4 | 13 | 22 | 4 | 13 | 22 | 4 | 13 | 22 |
| Estimate of Unique Visitors | 5,138 | 1,713 | 1,028 | 5,628 | 1,876 | 1,126 | 617 | 2039 | 1223 |
| Unique Compliant Individuals (38.5%) | 1,978 | 659 | 396 | 2,167 | 722 | 433 | 2355 | 785 | 471 |
| Unique Non-compliant Individuals (61.5%) | 3,160 | 1,053 | 632 | 3,461 | 1,154 | 692 | 3762 | 1254 | 752 |
median number of trail visits per respondent per week was three (Lindsey et al., 2015). If we assume the number of weekly visits by each user ranges from 1 to 5, it follows that monthly visits range from 4 to 22. Dividing our estimates of trail visits by these totals, we estimate the total number of unique individuals in June to range from approximately 1,000 to more than 6,100. Based on our sample observations that 61.5% of all individuals were not 100% compliant, we can estimate that somewhere between 600 and 3,800 unique individuals who visited the Sather Trail did not maintain social distancing in all interactions and were potentially exposed to risk. These numbers represent, respectively, 1.4% and 9% of the estimated trail traffic volumes for the month of June.

We use similar logic to extend this example. Surveys also provide evidence (i.e., self-reports) that many trail users use trails multiple times throughout the year. In an intercept survey conducted for the Minnesota Department of Natural Resources, more than half the respondents reported visiting daily, weekly, or monthly (MDNR 2020). Hence, it is likely that people who visited the Sather Trail in June (one of busiest summer months for trails in temperate climates like Minnesota) also include users from May, April, and the remainder of the prior calendar year. Thus, the cumulative total of unique users grows more slowly than the cumulative total of visits and total traffic counts past a point. Data were not available for estimating the cumulative totals of unique users, but for a variety of reasons, particularly public health concerns about the behaviors of individuals and exposure to risk, the differences between traffic counts, user-visits, and unique users are important.

Nonetheless, the quality of our traffic estimates is consistent with those routinely used in transportation planning. We minimized observation errors by training observers and limiting the numbers of observers used and minimized calculation error using occlusion and following best practice guidelines. Monitoring use is both more feasible with new technological advances and more important given declining resources for increasing public demands (English and Bowker 2018). For example, although mask wearing was not initially part of the monitoring protocols for this project (due to lack of mask guidance provided by the CDC and MDH when the observations began in late March), this should be added given the ongoing guidelines and empirical support for the efficacy of mask use (Howard et al., 2021). Specifically, videorecording and its manual reduction could document mask use and interaction duration measurements while computer vision and algorithm calculations could be automatically performed. Thus, reducing costly human based observation while providing additional data.

5. Conclusions

This study illustrates the value of public facility monitoring to inform planning and policy decisions. Integrated data revealed risk exposure for half of trail users and can be used to inform behavioral changes as a result of management or policy implementation. As more agencies successfully implement automated monitoring programs, our ability to assess the effects of major events like the COVID-19 pandemic will increase.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of interest

There are no conflicts of interest for the MS entitled ‘An integrated approach to monitoring and estimating COVID-19 risk exposure among leisure-time physical activity participants.’

Acknowledgments

Thank you to the numerous volunteers and interns who collected, entered and cleaned data through Baylor University, the University of Florida and University of Minnesota. The research team would like to acknowledge and thank Philip W. Lindsey for expert technical assistance in data analysis.

References

Agency for Toxic Substances and Disease Registry, 2021. Glossary of terms. https://www.atsdr.cdc.gov/glossary.html.
Centers for Disease Control, 2020. Prevent getting sick. https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/index.html.
Derks, J., Giessen, L., Winkel, G., 2020. COVID-19-induced visitor boom reveals the importance of forests as critical infrastructure. For. Pol. Econ. 118, 102253.
Deslatte, A., 2020. To shop or shelter? Issue framing effects and social-distancing preferences in the COVID-19 pandemic. J. Behav. Publ. Adm. 3 (1), 1–13. https://doi.org/10.30636/jbpa.31.158.
Eisenstein, M., 2021. What’s your risk of catching COVID? These tools help you to find out. Nature 589, 158–159.
El Esawey, M., 2016. Toward a better estimation of annual average daily bicycle traffic: comparison of methods for calculating daily adjustment factors. Transport. Res. Rec.: 2593, 28–36. https://doi.org/10.3141/2593-04.
English, D., Bowker, J.M., 2018. Special issue: visitor monitoring. J. Park Recreat. Adm. 36 (1).
Federal Highway Administration, 2018. Guide for Scalable Risk Assessment Methods for Pedestrians and Bicyclists. Federal Highway Administration, U.S. Department of Transportation, Washington D.C.
Federal Highway Administration, 2013. Traffic Monitoring for Non-motorized Traffic in: V1, Traffic Monitoring Guide. Federal Highway Administration, U.S. Department of Transportation, Washington D.C.
Hankey, S., Lindsey, G., Marshall, J., 2014. Day-of-year scaling factors and design considerations for nonmotorized traffic monitoring programs. Transport. Res. Rec. 2468 (1), 64–73. https://doi.org/10.3141/2468-08.
Howard, J., Huang, A., Li, Z., Tufekci, Z., Zdímal, V., van der Westhuizen, H.M., von Delft, A., Price, A., Fridman, L., Tang, L., Tang, V., Watson, G., Bax, C., Shaikh, R., Questier, F., Henrandez, D., Chu, L., Ramirez, C., Rimoin, A.W., 2021. An evidence review of face masks against COVID-19. Proc. Natl. Acad. Sci. Unit. States Am. 118 (4) https://doi.org/10.1073/pnas.2014564118.

Jones, T.E., Yang, Y., Yamamoto, K., 2018. Comparing automated and manual visitor monitoring methods: integrating parallel datasets on Mount Fuji’s North Face. J. Park Recreat. Adm. 36 (1), 22.

Lindsey, G., Ciabotti, J., Edwards, R., 2015. Technical Memorandum 2: results of COG trail intercept survey. Mid-Ohio Regional Planning Commission. Columbus, OH

Lopez B, Kennedy C, McPhearson T. Parks are critical urban infrastructure: perception and use of urban green spaces in New York City during COVID-19 Preprints 2020, 2020080620 (doi: 10.20944/preprints202008.0620.v1).

Lindsey, G., Falero, C., Lindsey, G., Petesch, M., Vorvick, T., 2017. Bicycle and Pedestrian Data Collection Manual. MnDOT Report No. MN/RC 2017-03, Minnesota Local Road Research Board. Department of Transportation, St. Paul, MN.

Minnesota Department of Health, 2020. Health officials announce new community-level strategies to slow COVID-19 in Minnesota. News Release. https://www.health.state.mn.us/news/pressrel/2020/covid031320.html. (Accessed 23 December 2020).

Metropolitan Council, 2016. Regional Parks System Visitor Study. City of Minneapolis,

Minge, E., Falero, C., Lindsey, G., Petesch, M., Vorvick, T., 2017. Bicycle and Pedestrian Data Collection Manual. MnDOT Report No. MN/RC 2017-03, Minnesota Local Road Research Board. Department of Transportation, St. Paul, MN.

Nosal, T., Miranda-Moreno, L., Krstulic, Z., 2014. Incorporating weather: comparative analysis of annual average daily bicyclist traffic estimation methods. Transport. Res. Rec. 2468 (1), 100–110.

Proulx, F.R., Schneider, R.J., Miranda-Moren, L.F., 2016. Performance evaluation and correction functions for automated pedestrian and bicycle counting technologies. J. Transport. Eng. 142 (3), 04016002.

Ramsey, County. COVID-19 situation update. https://data.ramseycounty.us/stories/s/Ramsey-County-COVID-19-Situation-Update/w4ux-wmze. 2021.

Rowley, G.L., 1978. The relationship of reliability in classroom research to the amount of observations: an extension of the Spearman-Brown formula. J. Ed Measurement 15, 165–180.

Snider, A.G., Hill, J., Simon, S., Herstine, J., 2018. A general framework for gathering data to quantify annual visitation. J. Park Recreat. Adm. 36 (1), 1.

South, E.C., Kondon, M.C., Razani, N.R., 2020. Nature as a community health tool: the case for healthcare providers and systems. Am. J. Prev. Med. 59 (4), P506–P510.

Theuring, J., 2016. Trail Uses Counting Program. Unpublished Technical Memorandum. Friends of the Little Miami State Park, Mason, OH.

Ziesler, P.S., Pettebone, D., 2018. Counting on visitors: a review of methods and applications for the National Park Service’s visitor use statistics program. J. Park Recreat. Adm. 36 (1), 39.