Open Journal of Forestry, 2023, 13, 1-12
https://www.scirp.org/journal/ojf
ISSN Online: 2163-0437
ISSN Print: 2163-0429

Research Note: A Multi-Method Approach to Monitor Recreational Trail Usage in Complex Spatial Settings

Sharon A. Jones[1*], Alex Junge[2], Ruth Dittrich[3]

[1]School of STEM, University of Washington, Bothell, USA
[2]Shiley School of Engineering, University of Portland, Portland, USA
[3]Pamplin School of Business, University of Portland, Portland, USA
Email: *sjones23@uw.edu

How to cite this paper: Jones, S. A., Junge, A., & Dittrich, R. (2023). Research Note: A Multi-Method Approach to Monitor Recreational Trail Usage in Complex Spatial Settings. *Open Journal of Forestry, 13,* 1-12.
https://doi.org/10.4236/ojf.2023.131001

Received: September 7, 2022
Accepted: November 12, 2022
Published: November 15, 2022

Abstract

Trail use by pedestrians has become more popular in the United States over the last decade although few studies explore the use of technology to monitor high use trails. Monitoring trail users is an important part of trail management and an optimal monitoring system usually depends on site-specific characteristics. The objective of this study was to demonstrate how using a multi-methods system to monitor backcountry trail usage in complex spatial settings can be a useful approach for collecting the information that trail managers need. Given the national growth in recreational hiking, we were particularly interested in exploring these issues for highly visited trails close to urban areas and selected a portion of the Larch Trail leading to the top of Multnomah Falls for the study. The multi-methods approach that we used included a combination of automated infrared sensor counts, manual counts, parking lot data from an inductive loop, and travel time estimates collected with low-energy Bluetooth sensors. We found that using multiple methods allowed for a cost-effective and rich data set that considered the site characteristics and the specific need of the trail managers. We expect that many backcountry trail settings have complex landscape and physical design without robust pre-existing baseline data and hope that our insights will aid trail managers as they strive for a sustainable balance between human use and landscape impact.

Keywords

Visitor Behavior, Trail Monitoring, Pedestrian Trails, Infrared Sensors

1. Introduction

1.1. Monitoring Pedestrian Trail Use

Between 2010 and 2021, the number of hikers in the United States increased by over 80% (Statista Research Department, 2022) and according to the American Hiking Society, most of their "*members hike on trails that are within* 60 *miles of home*" (American Hiking Society, 2015: p. 10). Several monitoring methods are currently used to count trail users including hikers as shown in **Table 1**. Some methods rely on direct measurements while others are based on indirect ways to monitor trail usage. Similarly, both automated and manual choices for monitoring exist. Despite the many options, recreational trail monitoring has traditionally been a manual process which can limit the amount of data collected, frequency for such collection, ability to differentiate the data spatially and temporally, and accuracy. In a recent study to estimate the value that recreational visitors place on sites that have been impacted by a significant wildfire (Lorber et al., 2021), we found that manual approaches were insufficient for the level of disaggregation needed spatially and temporally.

1.2. Study Objective

Our objective in this limited study was to demonstrate how by carefully considering

Table 1. Comparison of pedestrian trail monitoring techniques (assuming best practices) for backcountry settings (Yang et al., 2010; Shoji et al., 2008; FHWA, 2016; Fisher et al., 2018; D'Antonio et al., 2010; Groesbeck, 2019; Quality Counts, 2018).

Technique	User counts	Demographics	Multiple trail points	Other Data	Cost	Detects individual users	Other issues
Manual counts[2]	high accuracy	yes	yes[1]	--	$$$	yes	labor intensive
Self-registration books	depends	yes	yes[1]	variety	$	yes	unreliable
Video observations with software	medium accuracy	yes	yes[1]	--	$$$	yes	privacy concerns
Self-selected global positioning system	depends	no	yes	time, direction, speed, elevation	$$	yes	unreliable
Geo-tagged social media with software	medium accuracy	--	no	seasonal trends	$	no	--
Pressure/[2] Seismic sensors	unknown accuracy	no	yes[1]	--	$$	no	--
Infra-red[2] sensors	high accuracy	no	yes[1]	--	$$	no	--
Low-energy Bluetooth sensors	low accuracy	no	yes[1]	travel time, origin/ destination	$$	yes	topography impacts accuracy
Inductive loops	high accuracy	no	no		$$	yes (vehicles)	accuracy depends on vehicle usage. contained parking

[1]Requires multiple monitoring points along trail; accounted for in cost information; [2]Requires monitoring locations to have even traffic flow for high accuracy; this typically means relatively narrow trail widths.

the strengths and weaknesses of different trail monitoring methods, one can deploy a combination of methods that are optimized for both the unique characteristics and geography of a site and the goals for the trail manager. Given the national growth in recreational hiking and that recreational hiking may be viewed as a public benefit, we were particularly interested in exploring these issues for highly visited hiking trails that are close to urban areas.

2. Study Design & Background

2.1. Overall Plan

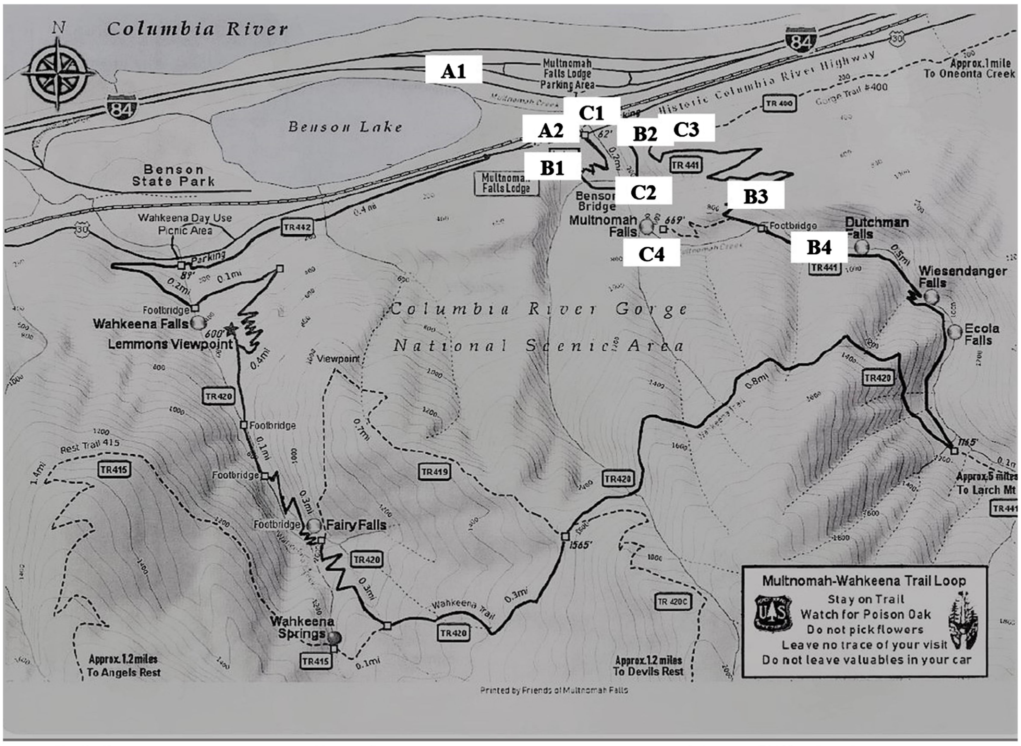
Our study design was based, in part, on the issues highlighted in a 2018 special issue journal about estimating recreation visitation (English & Bowker, 2018) as follows:

- Select a backcountry trail site that includes complex spatial features, a variety of visitor behavior, high visitor numbers with proximity (within 60 miles) to an urban area, and a cooperating trail management agency.
- Design the monitoring plan to include a combination of monitoring methods optimized for the primary trail management issues while cross-validating.
- Implement the monitoring methods based on primary trail management issues and using best practices.
- Evaluate the trail monitoring data to determine how well the various methods addressed the main issues.
- Consider particular insights from the multi-method approach, the challenges of deploying multiple methods, the usefulness of cross-validation, and the implications for broader application.

2.2. Backcountry Trail Selection & Site Description

We selected a spatially complex and highly visited trail within the Multnomah Falls (MF) recreation site that is managed by the US Forest Service (FS) as our study site. MF is located in the scenic Columbia River Gorge (Gorge), approximately 35 miles from Portland, Oregon. MF is estimated to be the most visited natural recreation site in the Gorge and the Pacific Northwest. Recently, the Eagle Creek Fire of 2017 impacted the stability and aesthetics of many of the trails in the Gorge (USDA Forest Service, 2014).

The overall MF Recreational Site is shown in **Figure 1**. The specific trail used for this study was a portion of a popular recreational trail located at MF known as the Larch Mountain trail. The Larch Mountain trail starts with beautiful views of a 620-foot waterfall at the base plaza, followed by another viewpoint of the waterfall and a historic bridge after a short ascent, and then views from the top of the waterfall after a steep incline. The trail then transitions to a much longer and less-travelled 4.5-mile loop trail that brings visitors back to the base of MF without returning through the portion of the trail where they started. For this study, our focus was limited to the portion of the Larch Mountain trail that spans MF from the base plaza to the top of the MF waterfall overlook; an in-and-out 2.2-mile



Label	Location	Type of Monitoring
A1	Overflow Parking lot	Inductive Loop
A2	Main Parking Lot	Assumptions
B1	Before Benson Bridge	Infrared & Manual Counts
B2	Turn Around Point	Infrared & Manual Counts
B3	Before Waterfall	Infrared & Manual Counts
B4	After Waterfall	Infrared & Manual Counts
C1	Base Plaza	Low-energy Bluetooth
C2	Benson Bridge	Low-energy Bluetooth
C3	Turn Around Point	Low-energy Bluetooth
C4	Top of Waterfall	Low-energy Bluetooth

Figure 1. Monitoring locations at the Multnomah falls trail.

trail with a 790 feet elevation gain known as the MF trail (or MF Trail Switchback).

The MF trail receives a high number of visitors with varying interests given that there are attractions for those with limited time and/or hiking ability as well as those interested in a more physical challenge. Some visitors come on tour buses that operate daily and have a short window at the site, while others are day-hikers from Portland, and many are in between. The MF trail widths are large in some areas while narrow in other areas and the overall access to the trail includes an expansive plaza at the base with multiple parking areas. Currently, the FS does not use routine automated technologies for trail monitoring at MF, although one of the parking lots (overflow) is automatically monitored by the Oregon Department of Transportation (ODOT) with an Inductive Loop (IL).

The FS describes the MF trail as having two parking lots and four trail segments based on presumed visitor behavior due to time limitations, available attractions, and physical challenges as follows.

Parking Area Main Lot: The main lot is located along the Historic Columbia River Highway across from the lodge which includes the Visitor Center. This lot has 83 parking spots. During peak hours, this lot is very crowded and anecdotal evidence suggests that some drivers become impatient and either park illegally or leave the site. Similarly, we observed that other drivers stay in their vehicles while their passengers exit to view MF at the base plaza and then return to the vehicles without parking.

Parking Area Overflow Lot: The overflow lot is located in between the I-84 east and I-84 west lanes (the main route to MF site from Portland OR) with a short walk to the base plaza. This lot has 178 regular parking spots and 12 oversized parking spots. It is common for this parking lot to be full during peak times when a gate closes to make it inaccessible to drivers from the eastbound lane.

MF Trail Segment 1: Visitors take a short walk from the parking lot(s) to the base plaza where they can view the 620-foot waterfall and an iconic site known as Benson Bridge. The official MF trail starts adjacent to the plaza.

MF Trail Segment 2: Visitors start on the trail and travel 0.1 miles with 120 feet of elevation gain to Benson Bridge. Upon reaching the bridge and staying for a period of time, some visitors return to the base of the falls. These visitors likely never intended to hike the trail and were focused on the opportunity to visit two main attractions within a short time period.

MF Trail Segment 3: The FS assumes that a significant portion of visitors attempts to reach the top of MF but turns around before reaching the top because they may not have enough time, the proper footwear, or be physically able to complete the relatively steep switchbacks.

MF Trail Segment 4: Visitors to this portion are able to complete the 1.1 miles to the top of the waterfall where they experience another attraction as they can stand on a platform that extends over a portion of the waterfall. Most of these visitors return to the base plaza the same way they came.

Beyond MF Trail Segment 4: A much smaller number of visitors continue an additional 4.5 miles past the top of MF on the Larch Mountain trail to Wahkeena Falls that eventually returns them to the base plaza. While these visitors are captured in the various MF trail segments leading up to MF, we did not consider the trail that extends beyond the top of the waterfall for this study.

2.3. Monitoring Plan and Method Selection

After better understanding they type of impacts along the expanse of the trail as identified by the MF trail managers, our focus for the monitoring study was on "counts" as a proxy for visitor demand/impact. Since the layout of the MF trail and the high number of visitors during most of the day minimizes the likelihood for off-trail exploration, we decided not to focus on an individual's origin-destination.

Our study approach combined infrared (IRs) sensors throughout the trail extent that were calibrated to manual counts, overflow parking lot data from an IL that were manually adjusted for the main parking lot and oversized vehicles, and low energy Bluetooth (BLE) sensors for visitor times that we used to triangulate with the other methods.

2.4. Monitoring Plan Implementation

Table 2 includes a summary of the visitor monitoring methods that we used for the MF trail study site while **Figure 1** shows their locations. Additional implementation details are below.

IR Sensor (*primary method for majority of MF trail extent*): We installed TrafX passive IR sensors on trees located immediately adjacent to the trail to avoid theft. The manufacturer suggests that the sensors should be located no more than 10 feet from the trail (TRAFx, 2018), however many trail sections did not have trees within 10 feet of the trail due to the Eagle Creek fire. We selected locations that avoided bends in the trail, steep slopes, viewpoints, congregation points, and junctions (Pettebone et al., 2010; FHWA, 2016). We placed IR sensors perpendicular to the trail at a height of 40 inches from the trail surface to avoid detecting animals while trying to minimize visibility to trail visitors (TRAFx, 2018). The MF trail width was between three to five feet for its entire length which is known to limit monitoring accuracy for the TRAFx counters (Pettebone et al., 2010). While there are other types of IR sensors available including overhead sensors, both cost and trail layout (tree loss from the fire) made these infeasible.

We automated the four IR sensors, labeled as B1, B2, B3, and B4 in **Figure 1** to continuously collect visitor data throughout the study period from July 1 2019

Table 2. Visitor monitoring method used for each segment of the Multnomah Falls trail (2019).

Trail segment	Primary monitoring method (summer 2019)	Cross-validation monitoring method
Base Plaza	Overflow parking lot inductive loop counts + main parking lot count assumptions (July 1 thru September 9)	Infrared sensor (July 1 thru September 9) for diurnal and weekly data patterns; Low-energy Bluetooth Sensors (July 3 thru July 9) to estimate visitor travel time for main parking lot assumptions
Start of Trail to Benson Bridge	Infrared sensor (July 1 thru September 9)	Manual count (1 hour to determine relative infrared sensor accuracy)
Benson Bridge to turnaround point	Infrared sensors (July 1 thru September 9)	Manual count (1 hour)
Turnaround point to top of waterfall	Infrared sensors (July 1 thru September 9)	Manual count (1 hour)
[*After the top of the waterfall to a separate 4.5-mile loop trail**]	Infrared sensors (July 1 thru September 9)	Manual count (1 hour)

*The section of the trail after the top of the waterfall is outside the focus of the project, however it was monitored to help account for visitors who may continue to the loop trail rather than hiking from the base plaza to the waterfall and back.

through September 9 2019. Since the IR sensors do not differentiate unique visitors and we treated the MF trail as an in-an-out trail, we divided the aggregate results for IR sensors B1, B2, and B3 by two to estimate the distribution of visitors across the trail extent. These three sensors span the extent of the main MF trail. We included IR sensor B4 (did not divide results by two) to estimate the number of visitors who continue to the 4.5-mile loop portion of the overall Larch Mountain trail.

Manual Counters (*calibration of the IR sensors*): While manual monitoring can be very accurate, a full-scale system for this project would have been cost prohibitive. Instead, we used manual counts for a more limited time period as a calibration tool for the IR sensors. Before the start of the project period on July 1 2019, two of our team compared manual counts among themselves to ensure consistency in counting. During the calibration, these two team members then sat near each IR sensor (B1, B2, B3, B4) for an hour and manually recorded the number of human visitors (including those below 40 inches in height) passing by the sensor both ways (up and down the trail). We also retrieved the number of visitors recorded by each IR sensor during the same hour and determined the accuracy assuming that the manual counts provided accurate benchmarks. **Table 3** shows the IR sensor accuracy compared to the manual counts that we used to adjust the IR sensor data during the project period.

Overflow Parking Lot Inductive Loop (*primary method for the base plaza*): As stated, ODOT maintains and monitors a permanent Reno A&E Model C-1000 two-channel IL sensor in the I-84 overflow parking lot. The IL sensor is marked at location A1 in **Figure 1** and counts the number of eastbound vehicles that enter the lot. We obtained the ODOT data for the time period of July 7 2019 through September 9 2019 and assumed there are 2.4 visitors in each vehicle visiting the Gorge based on a prior FS study (White, 2018). Since the 83-car main lot (A2 in **Figure 1**) that is closer to the Visitor Center has no form of monitoring, we assumed that all 83 spaces in the main lot are full from 7:00 am to 7:00 pm and empty from 7:01 pm to 6:59 am (based on IR count distribution) and added those assumed visitors to the IL counts. Unfortunately, we could not capture the additional visitors from tour bus and shuttle drop offs and illegal parking.

Table 3. Accuracy of infrared sensors relative to manual counts.

Sensor	Accuracy (including under 40 inches)
Start of Trail to Benson Bridge	96.8%
Benson Bridge to turnaround point	83.0%
Turnaround point to top of the waterfall	95.0%
[*After the top of the waterfall to a separate* 4.5*mile loop trail**]	98.1%

*The section of the trail after the top of the waterfall is outside the focus of the project, however it was monitored to help account for visitors who may continue to the loop trail rather than hiking from the base plaza to the waterfall and back.

BLE Sensors (*supplemental data about visitor time*): We installed four Bluemac x7s BLE sensors along the MF trail including one within the base plaza. BLE sensors (or beacons) can detect devices with Bluetooth ability (smartphone, watch, earbuds, etc.) even when they are not activated with each detected device interpreted as one trail user. These BLE sensors do not need an external power source and have built-in GPS. They provide a live data steam while also storing that data on the device. Because of the high demand for these sensors in the Portland metropolitan area they could only be used for the project between 5:00 pm on July 3 2019 and 4:00 pm on July 9 2019 with BlueMac Analytics responsible for installation, calibration, data collection and correction, and uninstallation while our team guided placement.

We installed one BLE sensor on each segment of the main portion of the MF trail labeled as C2, C3, and C4 in **Figure 1**. We also installed a BLE sensor in the main plaza labelled C1. After July 6 2019, the BLE sensor located near Benson Bridge (G) stopped collecting data. This BLE sensor was located near the waterfall which appeared to interfere with the live data stream and the problem was not discovered until after the device was uninstalled.

We used multiple BLE sensors at key locations across the trail extent to estimate typical travel times between trail segments by detecting unique devices as visitors moved across the trail. For urban settings, combinations of sensors working in tandem typically result in reduced error with higher detection and matching rates (Wang et al., 2011) though we do not have similar studies for backcountry trail settings. We did not have an independent data source to check accuracy.

3. Monitoring Results

3.1. The Main MF Trail

As expected and shown in **Figure 2**, the IR sensor data revealed a decrease in visitors along the MF trail as the elevation increased. It is also clear from the count distribution along the trail that almost 50 percent of visitors do not progress beyond Benson Bridge and very few visitors continue after (or enter) the MF trail to (from) the 4.5-mile Larch Mountain loop trail.

The diurnal pattern shows that as the day progresses to noon, the number of visitors traveling to Benson Bridge, site of the first IR sensor (lowest elevation), steadily increases with a noticeable dip from 12:00 pm to 2:00 pm when we observed that many visitors ate lunch at either the base plaza or at the restaurant located in the visitor lodge before starting the ascent or after having completed the ascent.

The data also shows that the diurnal pattern for visitors at the three higher elevation sensors is different than for the Benson Bridge sensor as the peak usage happens earlier in the day and before noon. While not presented, we also obtained weekly distributions. As a reminder, we could not use the IR sensors for those visitors who remained at the base plaza.

3.2. Open Base Plaza

As shown in **Figure 3**, the IL diurnal count distribution for the overflow parking lot mirrored that for the IR sensor that was located on the MF trail leading to Benson Bridge. There was a lag between the IL and IR data which we expected since a visitor has to first cross the base plaza before being counted by that IR sensor. The diurnal pattern indicates that on a typical peak summer season day,

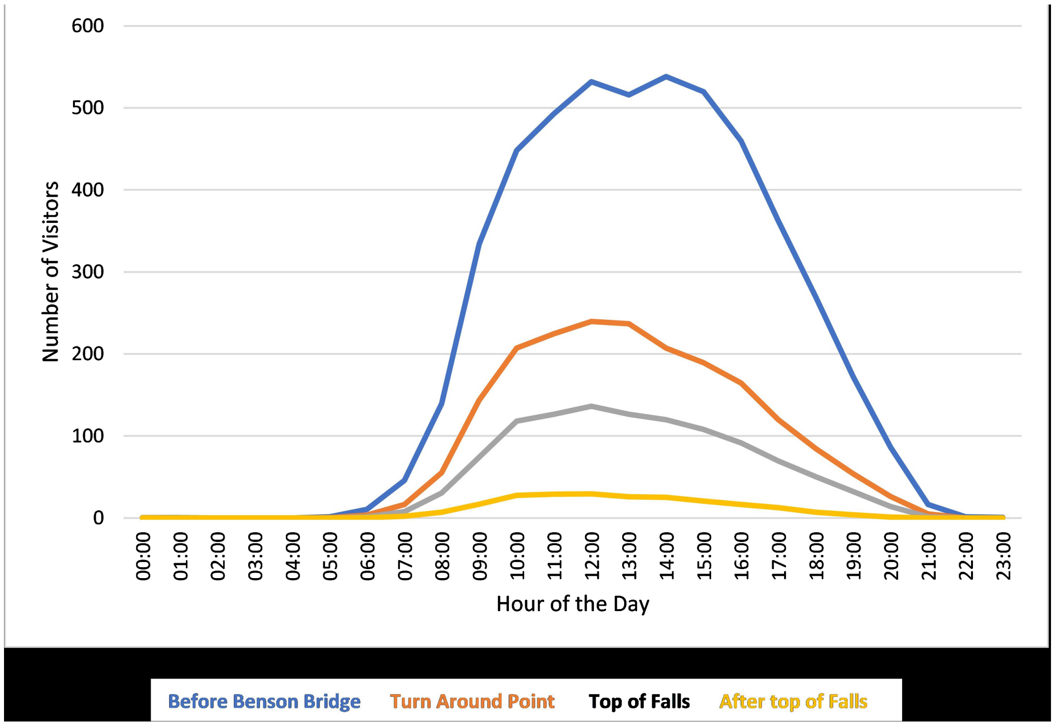


Figure 2. Infrared sensor counts-hours of the day.

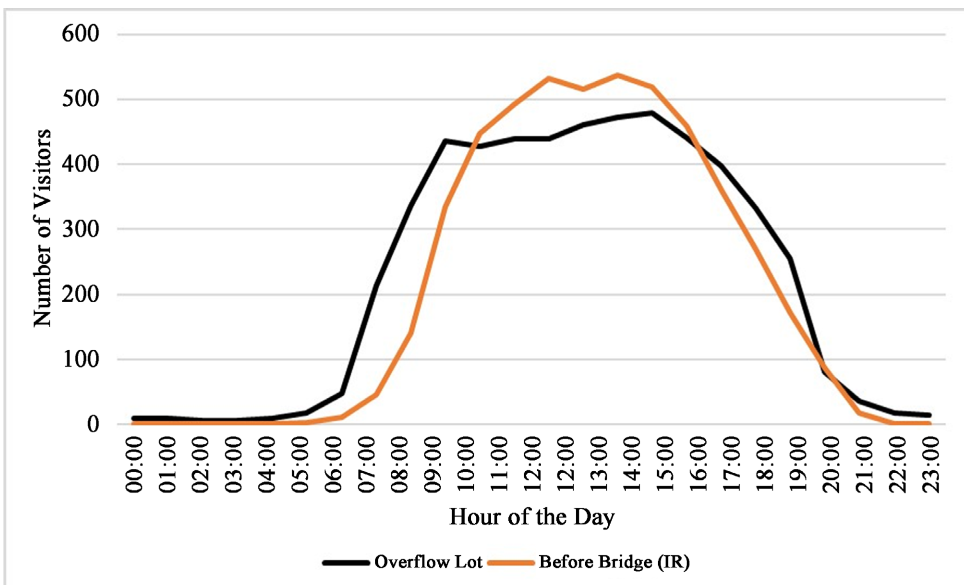


Figure 3. Overflow parking lot counts compared to infrared sensor counts before Benson Bridge-hours of the day.

the overflow lot was primarily used between 6:00 am and 8:00 pm with a relatively steady number of cars between 8:00 am and 5:00 pm which was likely when the 83-car main parking lot was full.

Table 4 presents a summary of the minimum, maximum, mean, and median walk times for three types of typical visitors to the MF trail based on the BLE monitoring data. Even accounting for time walking to the base plaza and observing the relevant attraction(s), the BLE data suggests that most visitors in the main parking lot are parked for less than an hour, and on average no more than 30 minutes. To determine a more refined estimate for the number of visitors to the base plaza, we combined the IL sensor data with an estimate for the main parking lot usage assuming that all cars in the main parking lot were replaced every 30-minute time period between 8:00 am and 5:00 pm.

The final estimate shows that there were approximately 8250 total visitors per day at the MF trail during July and August 2019. Figure 4 displays a summary of the average daily distribution of visitors across the MF trail during the 2019 peak summer season. For comparison, the MF Visitor Center visitor estimates suggested that an average of 18,500 people visited MF daily in July and August (White & Hinatsu, 2019) which is a significant overcount compared to our study.

Table 4. Maximum, minimum, and average travel times (minutes) from base plaza to various location on the trail using low-energy Bluetooth sensors.

Location	Sample size	Maximum	Minimum	Mean	25th percentile	Median	75th percentile
Base plaza to Benson Bridge	16,074	59.9	0.5	7.2	2.0	4.6	9.4
Base plaza to turnaround point	3994	59.3	0.5	12.7	6.5	10.9	16.4
Base plaza to top of waterfall	253	106.3	5	40.2	28.2	40.0	51.7

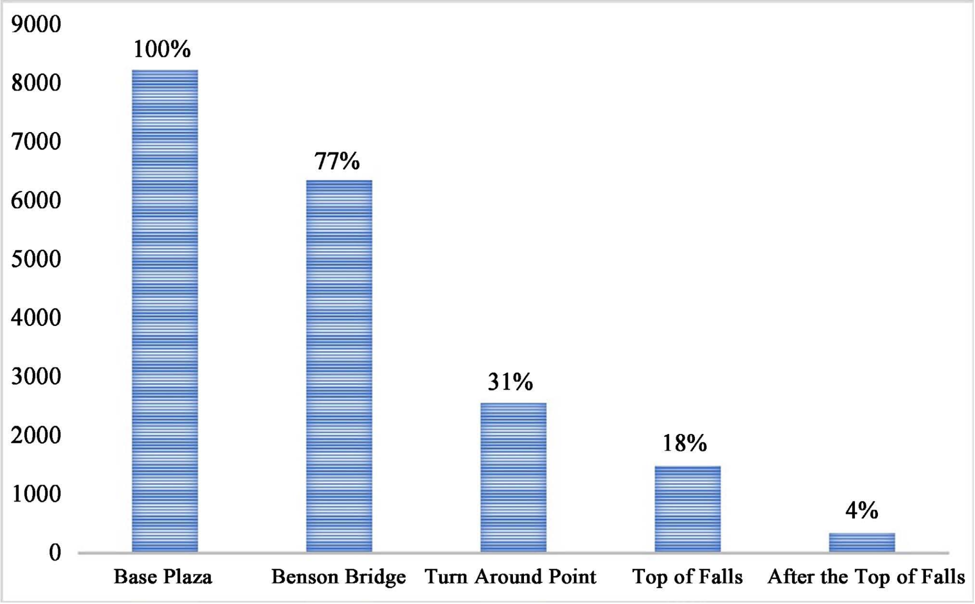


Figure 4. Average daily distribution of visitors across the Multnomah Falls Trail during the 2019 peak summer season (July and August).

18,500 is also one and a half times greater than the 2016 National Visitor Use Monitoring Program estimate for the entire Columbia River Gorge National Scenic Area (White, 2018) despite the limited use of MF in the first half of 2019 due to repairs from the Eagle Creek fire.

4. Conclusion

The objective of this study was to demonstrate how a multi-methods system to monitor backcountry trail usage in complex spatial settings can be a useful approach for collecting the information that trail managers need. The mixed methods approach allowed us to create a fairly detailed summary of trail usage over a two-month peak timeframe at a cost of approximately $10,000. Such an approach could be deployed for the off-peak season and the bridge season at MF to further refine the trail usage data. The approach could also be applied at regular intervals and in more focused ways to account for changes over time. Although we relied on a combination of the IL which was conveniently present, BLE, IR, and manual counts, various combinations of the other reliable techniques listed in **Table 1** could be used to provide an overall estimate of the total number of visitors to a site depending on resources, site constraints, and research needs.

Our limited study regarding trail monitoring approaches arose because we needed comprehensive trail usage data for a contingent valuation project. Because of participation bias, the cost for manual surveys, and inaccurate MF Visitor Center counts, we would not have been able to estimate the diurnal and weekly distribution of visitors within our two-month timeframe without a mixed-methods approach. This study demonstrated how careful consideration of the strengths and weaknesses of different trail monitoring methods within the context of the unique characteristics and geography of a complex recreational site can yield new insights for applied research regarding human impact on natural landscapes. We expect that many backcountry trail settings have complex landscapes without robust pre-existing baseline data and hope that our insights will aid researchers who may have similar funding and timeframe constraints.

Acknowledgements

The authors thank the University of Portland Shiley School of Engineering, the U.S. Forest Service, BlueMac Analytics, and the Oregon Department of Transportation for their assistance during this project. This project was supported by the Alliance/Katherine Bisbee II Fund Grant of the Oregon Alliance of Independent Colleges and & Universities.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

American Hiking Society (2015). *Hiking Trails in America: Pathways to Prosperity.*

http://www.AmericanHiking.org

D'Antonio, A., Monz, C., Lawson, S., Newman, P., Pettebone, D., & Courtemanch, A. (2010). GPS Based Measurements of Backcountry Visitors in Parks and Protected Areas: Examples of Methods and Applications from Three Case Studies. *Journal of Park and Recreation Administration, 28,* 42-60.

English, D., & Bowker, J. M. (2018). Introduction to the Special Issue on Visitor Monitoring. *Journal of Park and Recreation Administration, 36,* IX-X.

Federal Highway Administration (FHWA) (2016). *Traffic Monitoring Guide.* FHWA-PL-17-003. https://www.fhwa.dot.gov/policyinformation/tmguide/

Fisher, D., Wood, S., White, E., Blahna, D., Lange, S., Weinberg, A., Tomco, M., & Lia, E. (2018). Recreational Use in Dispersed Public Lands Measured Using Social Media Data and On-Site Counts. *Journal of Environmental Management, 222,* 465-474. https://doi.org/10.1016/j.jenvman.2018.05.045

Groesbeck, R. (2019). *Personal Interview.* 28 February 2019.

Lorber, C., Dittrich, R., Jones, S., & Junge, A. (2021). Is Hiking Worth It? A Contingent Valuation Case Study of Multnomah Falls, Oregon. *Forest Policy and Economics, 128,* Article ID: 102471. https://doi.org/10.1016/j.forpol.2021.102471

Pettebone, D., Newman, P., & Lawson, S. (2010). Estimating Visitor Use at Attraction Sites and Trailheads in Yosemite National Park Using Automated Visitor Counters. *Landscape and Urban Planning, 97,* 229-238. https://doi.org/10.1016/j.landurbplan.2010.06.006

Quality Counts (2018). *Bluemac Applications & Use Case*s. Unpublished.

Shoji, Y., Yamaguchi, K., & Yamaki, K. (2008). Estimating Annual Visitors Flow in Daisetsuzan National Park, Japan: Combining Self-Registration Books and Infrared Trail Traffic Counters. *Journal of Forest Research, 13,* 286-295. https://doi.org/10.1007/s10310-008-0085-5

Statista Research Department (2022, September 23). Number of Hiking Participants in the United States from 2010 to 2021. https://www.statista.com/statistics/191240/participants-in-hiking-in-the-us-since-2006/

TRAFx (2018). *TRAFx Infrared Trail Counter Instructions Part I and Part II.* https://www.trafx.net/downloads/TRAFx_Infrared_Trail_Counter_Instructions.pdf?v=190129

USDA Forest Service (2014). *Columbia River Gorge National Scenic Area Interagency Recreation Strategy Team.* Recreation Report and Recommended Interim Strategies. https://www.fs.usda.gov/recarea/crgnsa/recreation/natureviewing/recarea/?recid=30026

Wang, Y., Malinovskiy, Y., Wu, Y., & Lee, U. (2011). *Error Modeling and Analysis for Travel Time Data Obtained from Bluetooth MAC Address Matching.* Research Report T4118 Task 46.

White, E. (2018). *Visitor Use Report: Columbia River Gorge National Scenic Area.* USDA Forest Service.

White, E., & Hinatsu, S. (2019, April 19). *Personal Interview.*

Yang, H., Ozbay, K., & Bartin, B. (2010). Investigating the Performance of Automatic Counting Sensors for Pedestrian Traffic Data Collection. In *12th World Conference on Transport Research.* https://www.semanticscholar.org/paper/Investigating-the-Performance-of-Automatic-Counting-Yang-Ozbay/1025a2191f70f1a6da950c027fb122ffcfd34517