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The Effect of a Vehicle Diversion Traffic Management Strategy on Spatio-Temporal Park Use: A Study in Rocky Mountain National Park, Colorado, USA

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Executive Summary

Parks and Protected Areas (PPAs) across the Intermountain West region of the United States have observed an increasing trend in visitation in the past decade. Management of visitors' vehicles as much as the visitors themselves has created a challenge for managers. Experiencing PPAs by personal vehicle is a popular recreation experience. However, as PPAs accommodate historic levels of visitation, the infrastructure to accommodate these vehicles is strained. In response to periods of especially high use in the summer months, Rocky Mountain National Park (ROMO) actively limits access to the Bear Lake Corridor (BLC), one of the most popular day use areas of the Park. Because of limited parking infrastructure and capacities to provide a safe and quality visitor experience, ROMO redirects (i.e., diverts) vehicles away from the BLC. In July 2017, to examine the effect of this management intervention on visitor spatial behavior, participants intending to enter the BLC were given a Geographic Positioning System (GPS) device to track their movement throughout their visit to the Park. We performed a Distributive Flow analysis with the GPS data to understand the diversion's effect on traffic patterns of visitor vehicles diverted from the BLC. This study found that 21.2% of diverted visitor vehicles returned to the BLC after being redirected and 9% left the Park entirely, suggesting that there is a lack of substitutability for some visitors within the Park for the experience found along the BLC. During a period of redirection, Moraine Park, Endovalley, and Trail Ridge Road received increased levels of visitation as use was diffused across the Park, which may warrant increased monitoring of changes to the experiential and biophysical conditions in these locations. Diverted visitor vehicles made more stops, drove further distances and for a longer period of time than non-diverted visitor vehicles, but there was no significant difference in the length of time spent at points of interest within the Park. While the diversion was effective in temporarily reducing congestion in the

BLC, its effect on visitors' spatial behavior suggests that overall aggregate impacts to park resources and experiential conditions may be increasing as a result.

Keywords
Vehicle spatial patterns, park transportation, management interventions, GPS tracking, distributive flow analysis

Introduction

The management of visitors to Park and Protected Areas (PPAs) is focused on providing opportunities for immersion in nature and conservation for the enjoyment of future generations (Lemons, 2010). This often takes the form of indirect visitor management strategies such as education and interpretation of the resource and infrastructure design to encourage and concentrate use to areas with durable substrates (e.g., roads and trails). However, when necessary, managers of PPAs may also employ direct visitor management practices that limit or restrict use and freedom of choice of the visitor. Actions such as diverting visitors from high use areas when they exceed parking capacities can protect natural resources, visitor safety, or the quality of the visitor experience (Hammitt et al., 2015; McCool & Christensen, 1996).

The history of personal vehicles in National Parks extends more than a century when, in 1908, Mount Rainer National Park became the first unit to allow visitors to experience the Park by automobile (Harrison, 1995). This ultimately set in motion programs like "See America First" and "Mission 66." These programs supplemented National Park units with infrastructure like roads and highways to provide the opportunity to experience the Park by automobile and accommodate an increasing number of visitors (Manning et al., 2014). Today the management of automobiles in PPAs is multi-dimensional, providing visitors access and a park experience of driving for pleasure as well as a tool for managers to manipulate capacities and visitor use levels (Byrne & Upchurch, 2011; Orsi & Geneletti, 2016) and mitigate ecological disturbances to park resources (Monz et al., 2016). A study of visitor driving behavior in Grand Teton National Park classified 89% of the study participants as opportunistic, whose behavior was defined as tourists seeking the "highlights of the area, rather than as recreationists seeking a specific, activity-based experience" (Kidd et al., 2018). Whether this trend of opportunistic commuters is consistent across National Parks or if it represents an increasing proportion of visitors to National Parks has not been studied. However, management for this type of visitor has implications for PPA infrastructure planning and the balance of ecological, managerial, and social conditions.

National Parks in the Intermountain West region of the United States observed an inflection point in visitation around 2010. Over the next nine years, the average annual increase in visitation was 4% per year and, by 2019, visitation to Intermountain West National Parks had increased 42% from 2010 levels (National Park Service, 2020a). The trends were similar in Rocky Mountain National Park (ROMO), where the average yearly increase in visitation was 5%. By 2019, visitation to ROMO had increased 58%, which is approximately an additional 1.7 million visitors from 2010 levels of use (National Park Service, 2020b). Although this research was conducted in 2017, it is important to underscore the increase in visitation up to 2019, which is the most recent year visitation data are available. This increase in visitation and personal vehicle use has challenged ROMO managers' ability to effectively accommodate this unprecedented number of visitors with the Park's existing infrastructure.

Since 2016, in response to record levels of visitors and personal vehicles during periods of high use (i.e., summer months), managers of ROMO instituted a direct management strategy by diverting visitors away from the Bear Lake Corridor (BLC) when capacities of the parking areas along the corridor were reached. While ROMO's intervention strategy was effective in alleviating pressure on the parking capacities within the BLC, managers were unsure of how to evaluate the effectiveness of the management action. Specifically, the primary concern was where visitors were being displaced to and if the diversion affected the total number of visitors to the BLC. Additionally, we sought to understand if there were any observable visitor coping or behavioral responses, like substitution (Brunson & Shelby, 1993) or rationalization (Manning & Valliere, 2017), that the literature suggests follows the management intervention like this use restriction.

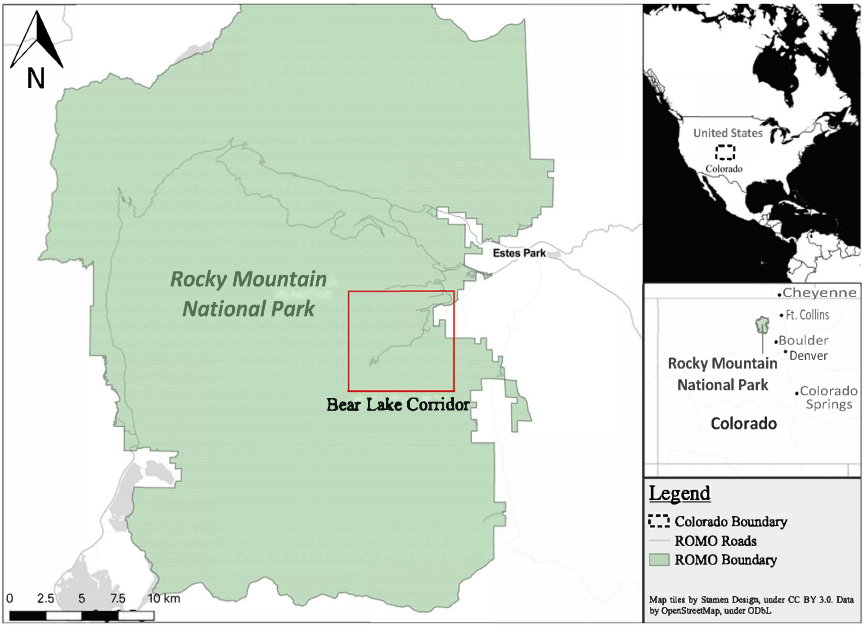
The focus of this study was to evaluate the effects of the vehicle diversion on visitor travel patterns and behaviors through a quasi-experimental study design. Research exploring visitor spatial behavior in PPA settings has widely employed GPS tracking to understand spatial patterns of use and connect recreation use with biophysical impacts (D'Antonio & Monz, 2016; Hallo et al., 2012; Kidd et al., 2018; Riungu et al., 2019). GPS visitor data that has been employed in other studies also focused on transportation in ROMO including Lawson et al. (2011) which used visitor routes to model and simulate the effect of shuttle systems on crowding and the quality of the visitor experience (Lawson et al., 2011). GPS tracking of visitors provides a less biased method of collecting trip itineraries and inferring aspects of visitor behavior from movement (Taczanowska et al., 2008); and in this study to understand the visitor response to temporal restriction of use along the BLC.

Methods

Study Site

ROMO is located an hour and a half northwest of the Denver Metropolitan Area (Colorado, USA), which has experienced significant population growth in the past decade, reaching a population of 3.5 million (U.S. Census Bureau, 2021). ROMO is one of the highest parks in the nation with 77 peaks of the Mummy Range exceeding 3,650 meters. An icon of ROMO, Bear Lake sits in the eastern quadrant of the Park and is easily accessible by vehicle, making it one of the busiest areas. The road leading to Bear Lake is 15 kilometers long and provides access for opportunities to hike, fish, boulder, and stop at vistas. The road dead-ends at the lake and there are a limited number of designated parking spots along the BLC (Figure 1). Trail Ridge Road, Endovalley, and Moraine Park are other highly sought out areas for visitors. Trail Ridge Road is a scenic drive offering vista lookouts and is the most direct route to the Alpine Visitor Center. Endovalley is a picnic area next to Fall River. Moraine Park is the last vehicle permitted area on the BLC before the diversion and offers reserved campsites and trails to alpine lakes.

Figure 1
Study Area Defined within Rocky Mountain National Park, Colorado, USA



In an attempt to reduce the number of personal vehicles in the Park, a shuttle service is provided running from the Estes Park Visitor Center to Bear Lake, with several opportunities to stop in between. Current operating hours are from 0700 to 1930, with a Bear Lake shuttle leaving every 10 to 15 minutes. Pettebone et al. (2011) found that visitors prefer to use personal vehicles along the BLC. However, some visitors are willing to use the established shuttle system to avoid road traffic. Yet, concentrated use of personal vehicles along the BLC continues to be a problem.

Spatial Data Acquisition

We conducted this quasi-experimental design study in July 2017, stratifying the sampling across weekdays and weekends throughout the month. Diversions from the corridor occurred daily at around 1000 hours and typically lasted for about two hours, creating our two sample groups: the control being the non-diverted visitor vehicles and the treatment being the diverted visitor vehicles navigating the management intervention. Sampling occurred from 0945 to 1300 (i.e., before, during, and after the diversion) using a stratified random visitor vehicle intercept technique (Vaske, 2008). We were somewhat limited in our study, as it was impractical to eliminate the BLC restriction during high periods of use. While it would be interesting to observe how visitors cope without a management intervention, it would compromise visitor safety to ignore the BLC's visitor capacity. During times of vehicle diversions, if one car was exiting the BLC while another vehicle was arriving, the arriving vehicle could enter the corridor. This intervention strategy did not allow for cars to queue in hopes of getting into the BLC sooner, only allowing vehicles to bypass the diversion if they arrived at the opportune time.

Visitor parties who agreed to participate in the study were provided a Garmin e-Trex 10 GPS unit (Garmin International, Olathe, KS, USA) at the BLC diversion location (i.e., just south of Fern Lake Road) and were asked to keep it in their vehicle for the extent of their visit to the Park. Vehicle location points were recorded every 5 seconds to provide an accurate depiction of vehicle movement and identify stop locations. Visitors were instructed to return the GPS units to drop boxes located at the primary entrance points of the Park as they left (Kidd et al., 2018). A total of 321 GPS tracks were collected during the sampling period, with an overall acceptance rate of 72%. Data preparation and analysis were performed in ArcMap 10.6.1 (2019, Environmental Systems Research Institute (ESRI), Redlands, CA, USA).

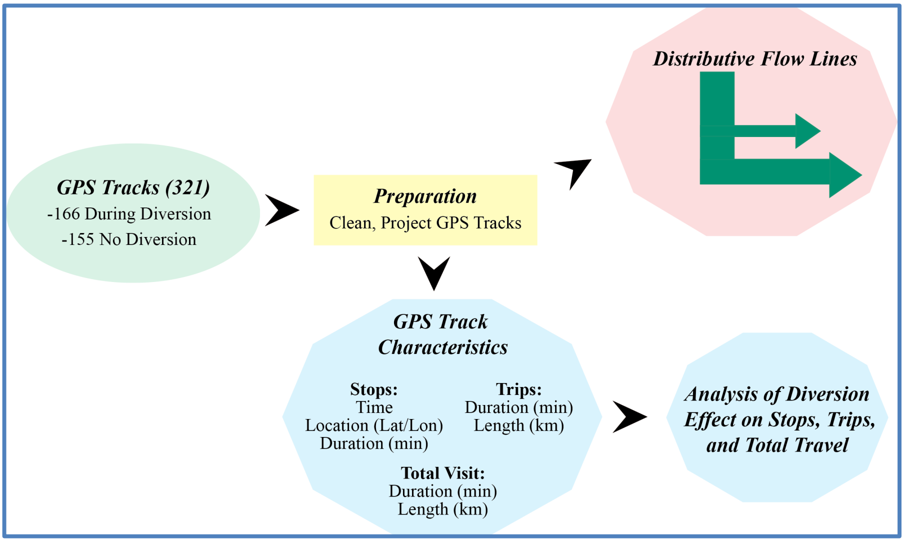
Data Analysis

Of the 321 GPS tracks collected, 166 tracks were collected by visitor vehicles during the diversion and 155 tracks before or after the diversion was in place. The GPS tracks were imported as point features in ArcMap and projected to Universal Transverse Mercator (UTM) Zone 13N. Redundant points collected when the GPS unit was returned to the drop box were eliminated before analysis. We inspected each track to ensure the GPS points were consistent with the Park's road system and human behavior (Kidd et al., 2018). Each track was analyzed to understand the following about where visitors stopped: location, arrival time, departure time, and duration of each stop. A visitor was considered stopped when the vehicle was in the same position for two minutes or more and located in a parking lot or place to pull off the road, including overlooks, trailheads, facilities, or roadside pullouts. Additionally, GPS tracks were analyzed to understand how long visitor vehicles stayed in the Park (which represents the time from when the GPS was handed out at the diversion location until the GPS unit was placed in the drop box) and how far they traveled upon receiving the GPS unit. We were unable to analyze what visitor vehicles did before attempting to enter the BLC. The coordinates for each stop location, stop times (durations and occurrences), travel times, trip duration, and distance traveled were recorded in Microsoft Excel (Microsoft Corporation, Bellevue, WA, USA). Stop time was calculated by subtracting the arrival time at the stop point from the departure time from that location. Travel time was calculated by subtracting the departure time from the preceding stop point from the arrival time to the next stop point. Trip duration was calculated by subtracting the arrival time at the handout location from the time the GPS unit was turned in to a drop box location. Distance from each point to the next along the route was calculated in kilometers using Google Maps (2019, Google, Mountain View, CA, USA) for its routing feature's ease of use. Using the Excel file, the total number of stops, total time stopped, average time spent, median time spent, and average arrival time at each stop were determined for the diverted and non-diverted tracks (Figure 2). Group difference statistics were determined with T-tests with SPSS statistical software (v.23, IBM Corp., Armonk, NY, USA).

Spatial Analysis

Distributive Flow Lines are a thematic cartography technique used to visualize the direction and magnitude displaying movement of people, resources, or goods (Stanford University & Steiner, 2019). When examining visitor spatial behavior, the Distributive Flow Lines produce intuitive visualizations of aggregate traffic flows based on vehicle or visitor volumes and attractions to specific areas of the study area. An initial use of flow lines in the context of visitor management came from Lucas (1980),

Figure 2
Schematic Flowchart of Spatial Data Preparation and Analysis



where visitor use on trails in Wilderness areas across the Western United States was plotted based on survey responses of routes and trail use as well as visitor entry points. Connell and Page (2008) used a similar approach with a participatory GIS visitor trip itinerary questionnaire to visualize patterns and concentrations of automobiles with an aggregate or Distributive Flow analysis in Loch Lomond and Trossachs National Park, Scotland. Connell and Page (2008) found the volume of vehicles fluctuated throughout the parks based on primary and secondary points of interest to the visitors.

We conducted a network analysis using the Distributive Flow Lines tool in ArcMap to demonstrate the movement differences of visitors in vehicles throughout the Park. Using the BLC diversion location as the source feature and the other stop locations as destination features, the flow lines were confined to the ROMO road system by including an impedance feature to snap the lines to the roads. The line thickness results were manually classified ordinally; low (1-50 vehicles), moderate (51-125 vehicles), and high (126-235 vehicles) based on the volume of vehicle tracks from our sample that accessed certain areas of the Park.

A Kernel Density difference plot was created to account for time spent in each area. Two plots were generated, one for the non-diverted and another for the diverted visitor vehicles, to visualize high use areas. Using the Raster Calculator tool in ArcMap, a difference map was created to show where the proportions of use were different across visitor vehicle groups.

Results

Manipulation of the traffic diversion was coordinated by National Park Service Law Enforcement who opportunistically permitted 43 of the 151 vehicles queuing during the diversion time period to enter the BLC when they believed enough vehicles had exited to make parking spots available. Because the BLC was already beyond the parking capacities which triggered the diversion, these visitor vehicles remained in the diverted group for analysis purposes to understand travel behavior under those conditions. Of the remaining 151 vehicles, half of the visitor vehicles (50.3%) found other parts of the Park to visit outside of the BLC and did not return to the BLC during our sample period. The remaining diverted visitor vehicles (21.2%) returned to the BLC when traffic restrictions were lifted after visiting other parts of the Park. These visitor vehicles spent an average of 3 hours and 22 minutes elsewhere in the Park before returning to and entering the BLC.

Once informed of the BLC diversion, 9% of diverted visitor vehicles ($N = 15$) were observed leaving the Park after not being permitted into the BLC. By omitting the 15 GPS tracks of visitor vehicles that left the Park immediately, we compared 151 tracks that stayed in the Park when redirected from the BLC to 155 tracks that arrived at the BLC before or after the diversion. Each analysis only applies to the observed portion of the visitor vehicles' time in the Park with a GPS unit. We found the total number of stops, total driving duration, total time in ROMO, and the total distance traveled were significantly different between visitors who were diverted during the restriction and those who entered the BLC before the restrictions (Table 1). Diverted visitor vehicles stopped more frequently but had greater variation in the number of stops. The diverted group also traveled greater distances throughout the Park and for a longer duration of time. Diverted visitor vehicles drove an average of 20 minutes longer than non-diverted visitor vehicles and traveled an average of 9.4 kilometers more than non-diverted visitor vehicles. Additionally, the diverted visitor vehicle group spent 33 more minutes in the Park than non-diverted visitor vehicles; however, the total stop duration at points of interest was not different between the visitor vehicle groups.

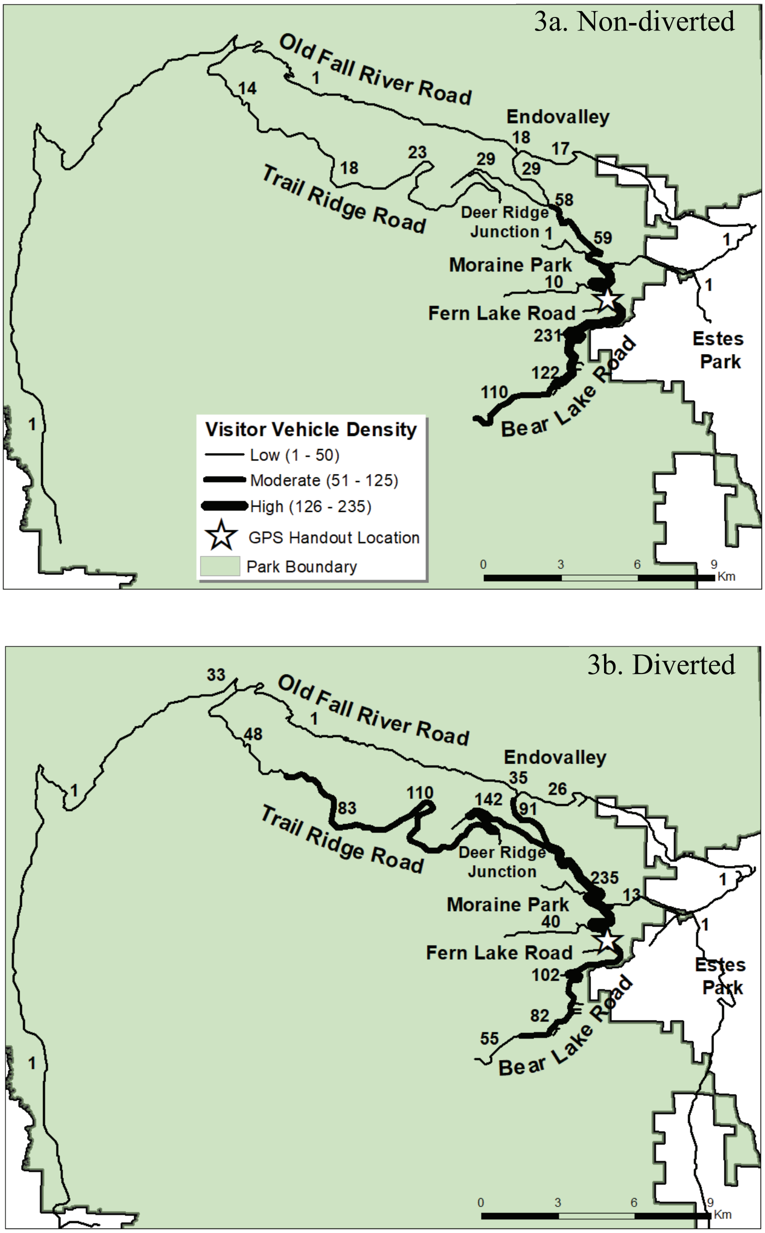
Table 1
Observed Trip Differences Between Non-Diverted and Diverted Visitor Groups

	N	Mean	Standard Deviation	*t*-score	*p*-value
Total Number of Stops				-3.341	.001*
Non-diverted	155	3.1	1.7		
Diverted	151	3.9	2.3		
Total Stop Duration[1]				-1.190	.235
Non-diverted	155	02:23:00	1:36:00		
Diverted	151	02:37:00	1:46:00		
Total Driving Duration[1]				-4.384	.000*
Non-diverted	155	00:37:13	00:26:08		
Diverted	151	00:57:07	00:49:28		
Total Duration in the Park[1]				-2.547	.011*
Non-diverted	155	03:01:00	1:40:00		
Diverted	151	03:34:00	2:06:00		
Total Distance Traveled (km)				-3.219	.001*
Non-diverted	155	27.3	17.6		
Diverted	151	36.7	31.5		

[1]Mean calculated using hh:mm:ss formatting
*Significant Difference
T-scores and *p*-values were determined by comparing the diverted visitor group to the non-diverted visitor group.

Vehicle traffic patterns for the non-diverted group show high use volumes in areas along the BLC with some movement in the northern area of the Park near Deer Junction (Figure 3a). The map for the diverted group depicts increased use in the northern areas of the Park, including Moraine Park (Fern Lake Road), Endovalley, and Trail Ridge Road. There was still use along the BLC indicating diverted visitor vehicles were still able to access the corridor at some point during their visit (Figure 3b). The great-

Figures 3a. and 3b.
Distributive Flow Analyses: Volume of Non-Diverted and Diverted Visitor Vehicles



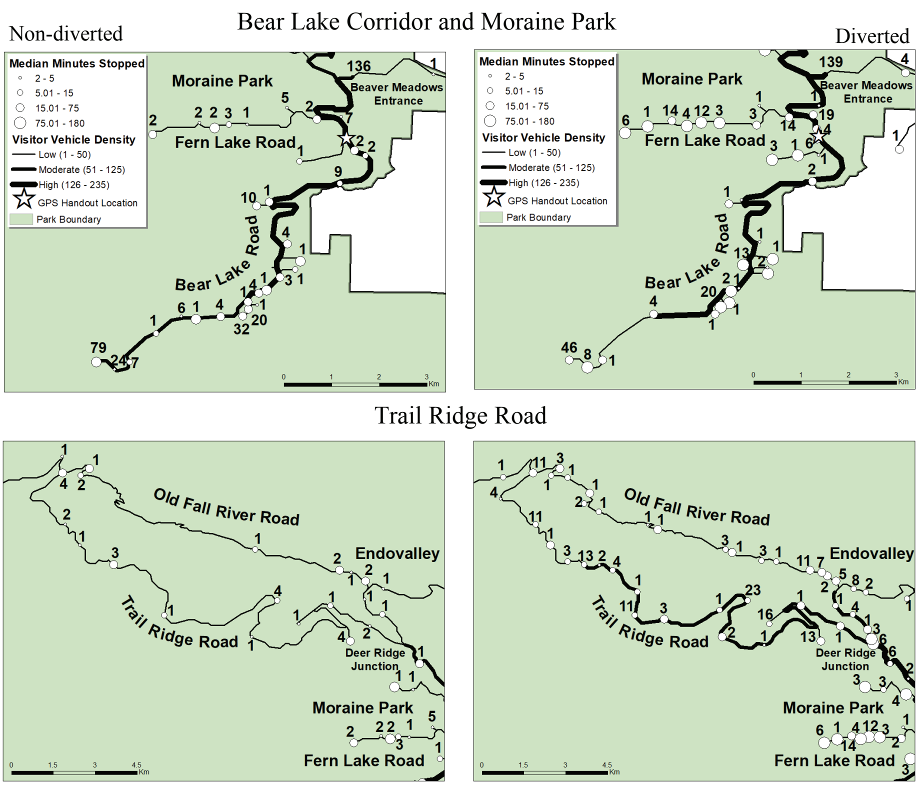
Note: a. The volume of non-diverted vehicles b. the volume of diverted vehicles. Thicker lines indicate higher volumes of traffic as opposed to thinner lines that indicate less traffic. The numerical values on the maps account for the number of vehicles from our sample that accessed that section of road.

est variations between the two groups are focused in the central area of the Park. A greater volume of non-diverted visitor vehicles accessed the BLC, while diverted visitor vehicles utilize more of Trail Ridge Road and Moraine Park.

To investigate how the groups differed in their stop times, large scale maps of these areas were created for visual comparison (Figure 4). Non-diverted visitor vehicles stopped more along the BLC. Still, the results suggest they did not stay as long as diverted visitor vehicles who also made it to the corridor based on the median stop times in these locations. Diverted visitor vehicles visited Moraine Park (Fern Lake Road), Trail Ridge Road, and Old Fall River Road more frequently and spent more time in these locations than non-diverted visitor vehicles. Specifically, there is concentrated use of diverted visitor vehicles in Endovalley and short but frequent stops were made along Trail Ridge Road. The BLC was the most popular corridor throughout the Park for both groups.

Figure 4

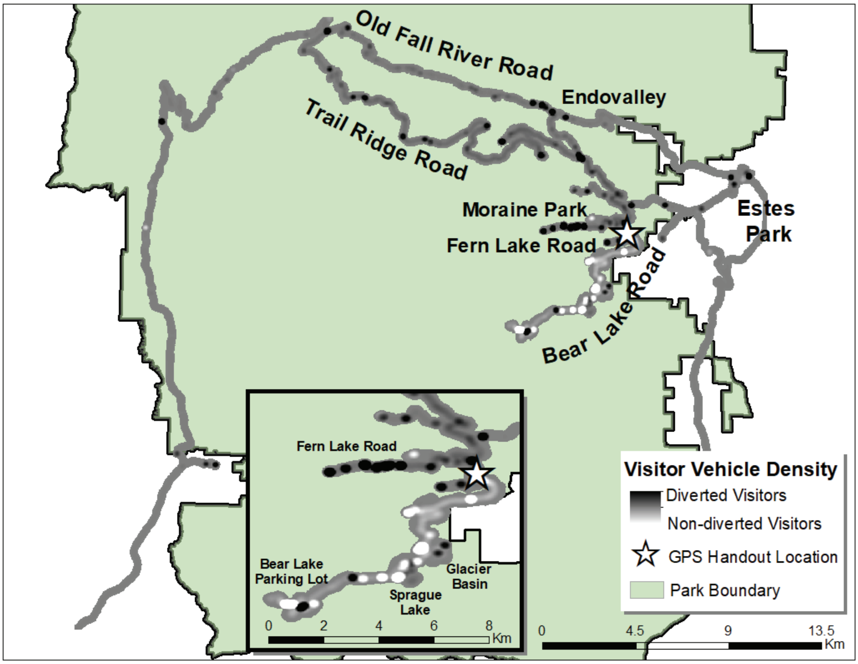
Distributive Flow Analyses: Park Regions of Particularly Different Use between Non-diverted and Diverted Visitor Vehicles



Note: Thicker lines indicate higher volumes of traffic as opposed to thinner lines indicating less traffic. The white circles are proportional to the median stop time at a point of interest. The numbers above each stopping point indicate the total amount of stops made by vehicles in our sample.

Finally, diverted visitor vehicles drove greater distances but did not stay in the Park or stop at points of interest longer than the non-diverted visitor vehicles. Given the disproportionate amount of spatial use between the two groups across the Park, the Kernel Density difference plot visualizes how much more area diverted visitor vehicles covered compared to non-diverted visitor vehicles (Figure 5). The redirection appears effective at diverting visitor vehicles to different locations throughout the Park. Specific areas of high use for diverted visitor vehicles include: Fern Lake Road, Endovalley, and areas along Trail Ridge Road. Non-diverted visitor vehicles have greater densities at the Bear Lake Parking Lot, Glacier Basin Park and Ride, Sprague Lake, and other parking areas along the BLC. Areas of higher concentrations of either visitor group indicate high density resulting from either the number of visitor vehicles in this area or the amount of time the visitor vehicles spent here.

Figure 5
Kernel Density Difference Plot between Non-Diverted and Diverted Visitor Vehicles



Note: The white areas along the BLC are areas of higher densities of non-diverted vehicles compared to diverted vehicles. The black areas are higher densities of diverted vehicles compared to non-diverted vehicles and are more disbursed throughout the Park. Grey areas represent areas used by both non-diverted and diverted visitors. Areas with darker grey colors indicate longer time spent or more use from diverted visitor vehicles (Trail Ridge Road). Lighter grey areas indicate longer time spent or more use from the non-diverted group (Bear Lake Road). The inset map provides further detail on visitor use distribution in and around the Bear Lake Corridor.

Discussion

We were able to observe distinct differences in travel patterns and behaviors between diverted and non-diverted visitor vehicles. Diverted visitor vehicles made more stops, spent more time driving, and traveled a greater distance within the Park. The high percentage of visitor vehicles that returned to the BLC (21.2%) and the number of vehicles observed leaving the Park (9%) after being diverted suggests that the visitor experience at Bear Lake represents a combination of environmental, social, and managerial conditions in high demand from the visitor that cannot be found anywhere else in the Park. These visitors demonstrated a spatial coping behavior (Brunson & Shelby, 1993) by loitering until they can return to their primary area of interest. During this period of temporal displacement, these visitor vehicles stop at more locations in periphery areas of the Park for short periods of time, similar to the opportunistic commuters described by Kidd et al. (2018). Further study regarding the substitutability of the visitor experience in the BLC would be necessary to understand if the benefits and outcomes of the setting are exclusive to Bear Lake and should also investigate the emotional and symbolic importance dimensions of place attachment to the area (Manning, 2011).

Diverted visitor vehicles demonstrated a pattern of more diffuse movement throughout the Park. Trail Ridge Road, which provides access to ROMO's highest elevations and features similar alpine viewsheds as the BLC, saw increased levels of visitation from diverted vehicles. Consequently, these visitor vehicles drove further distances than visitor vehicles that were not diverted. By diverting visitors away from the BLC, visitor vehicles dispersed to less used areas, which creates the potential for more diffuse ecological disturbance to the natural resource and may warrant increased ecological and visitor use monitoring and management. Additionally, based on the number of locations stopped at in the non-diverted group along the BLC, there are indications of increased informal or roadside parking, which can be detrimental to fragile vegetation areas and denude areas surrounding the roads.

Despite the restriction diverting visitors away from the BLC, nearly half of the visitor vehicles were still able to access the BLC at some point during their visit. This behavior extends the temporal extent of the period of high use at Bear Lake and along the BLC throughout the day as a potential result of the diversion. Past research in ROMO has demonstrated a significant ecological disturbance to habitat connectivity as a result of spatially small but intense areas of visitor use (Gutzwiller et al., 2017). Wildlife is also sensitive to temporal patterns of human use (Newsome et al., 2005). High levels of visitor use extending longer durations may further displace or functionally disconnect patches of habitat, particularly for wildlife with small spatial ranges.

The results of this study may not be generalizable to all ROMO visitors, as the focus of this study was on visitors to ROMO's Bear Lake Corridor. Additionally, we were limited to the extent that we could infer visitor party intentions and preferences, as no questionnaire was used to provide context to visitors' behavior, their intended versus realized trip itineraries, motivations, and normative thresholds of crowding. Given these data were collected in 2017, it is also possible that visitor spatial behavior may have changed and current visitors may cope with a diversion differently. Finally, as mentioned, this study was limited to the extent that the diversion times and frequency could be manipulated and controlled. Diversion times were regulated by park management and could not be removed to understand how visitors would respond to increased congestion and limited parking infrastructure in the corridor without a management intervention.

This study contributes to the growing corpus of research on park transportation which underscores the importance of planning and management of transit systems within parks and long-term sustainable transportation solutions (Manning et al., 2014;

Orsi, 2015). We found that because of the management intervention to divert visitors away from the BLC, visitor vehicles diffused use across the Park, creating the potential for unintended consequences of crowding and resource impacts at these locations. Yet many visitor vehicles eventually returned to the BLC. As a potential result of the diversion, the additional kilometers these diverted visitor vehicles traveled on park roads creates increased vehicle exhaust emissions, road noise, wildlife disturbances and possible collisions, and extends the temporal use to the BLC.

Management of visitors and their personal vehicles is a challenge across many PPAs, but the solutions are typically contextual, and what may work in some units may not work in others. Cole (1997) argues that the reactive management strategies most commonly used in PPAs, such as diverting vehicles from heavily used areas, are taking away resources from important proactive measures that are needed to prevent degradation of other natural areas. Cole (1997) suggests prioritizing more lightly used natural areas by establishing condition thresholds, monitoring programs, and restrictions when necessary because these areas are more responsive to management actions. As our results have shown, redirecting visitor vehicles from high use areas does not reduce the overall impact to the Park and disperses use to other potentially more ecologically sensitive areas. If the goal is to establish capacity limits on vehicles, the Park may benefit from a more parkwide approach and operationalize these quotas at the Park entrance using the BLC as an indication that capacity has been reached.

Management Implications

By implementing the BLC vehicle diversion, ROMO managers have recognized the roadway and parking lot congestion issue along the corridor. Our findings demonstrate how diverted visitor vehicles spatially respond to the displacement and are redirected to other areas of the Park. However, further research is required to develop a limit of personal vehicles and where they should park in the BLC, evaluate trade-offs of scenarios limiting access to the BLC or the Park, and understand if the benefits and outcomes of the Bear Lake visitor experience are exclusive to that region of the Park. ROMO managers have identified the need for data on day use visitation in high interest areas, such as BLC in the 2013 Foundation Document (National Park Service, 2013, p.16), an implement of park planning.

We propose further study of day use visitors' motivations, desired itineraries, evaluations of trade-offs, and preferences of social and ecological conditions to inform park management and planning efforts to better understand this growing visitor demographic. This information can help inform the appropriateness and acceptability of direct management strategies such as a reservation system, promotion of less visited areas of the Park which provide a similar visitor experience as the BLC, investments or expansion of traffic and parking infrastructure, and improved communication and visitor messaging. Further, reducing the number of vehicles entering the Park or the BLC by establishing daily limits on the number of vehicles that enter the corridor may relieve some of the issues associated with current traffic congestion conditions. Adaptive management strategies of lottery or reservation systems, such as the visitor management system in place at Half Dome in Yosemite National Park (Pettebone et al., 2013), pace the number of visitors or vehicles in areas that have high value for the visitor to ensure high quality visitor experiences, sustainable management of the natural resource, and safer high use area protocols. Reservation systems can create planned and consistent levels of visitor use throughout the day, week, and seasons and can be advantageous to managers to coordinate and allocate staff and resources. While we recognize that reservation systems must provide equitable access to Public Lands for all, the visitors who are most burdened by these systems are those who have not planned and prepared for their visit. To provide opportunities for visitors unable to prepare weeks in advance, a block of permits could also be released closer to the visit time, or available on a first-come, first-serve basis on the day of the visit.

Conclusion

From this research, managers can understand potential new patterns of park visitor movement that may result from management actions such as road closures and diversions and plan for the resultant impacts from displacement and changes in visitor use levels. This direct management solution eased the burden of congestion and overuse in one area but diffused visitor vehicle use leading to potential resource and social issues in other areas and likely increased the overall negative environmental impact of a visit to the Park. Diverted visitor vehicles having returned to the BLC at a later time suggests that, for many visitors, there is a lack of substitutability within ROMO for the visitor experiences provided by the BLC. Anticipating continued increased use, the Park might consider using the BLC as an indicator of park capacity and limiting the number of visitors at the Park entrance as opposed to dispersing visitors to other locations, potentially increasing the experiential and biophysical impacts in more sensitive areas. A continued challenge for managers is allowing visitors to have an equal opportunity to experience their most desired locations in the Park.

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References

Brunson, M. W., & Shelby, B. (1993). Recreation substitutability: A research agenda. *Leisure Sciences, 15*(1), 67–74. https://doi.org/10.1080/01490409309513187

Byrne, W., & Upchurch, J. (2011). Reducing congestion at grand canyon's south rim. *Institute of Transportation Engineers, 81*, 50–55.

Cole, D. N. (1997). Recreation management priorities are misplaced—allocate more resources to low-use wilderness. *International Journal of Wilderness, 3*(4), 4–8.

Connell, J., & Page, S. J. (2008). Exploring the spatial patterns of car-based tourist travel in Loch Lomond and Trossachs National Park, Scotland. *Tourism Management, 29*(3), 561–580. https://doi.org/10.1016/j.tourman.2007.03.019

D'Antonio, A., & Monz, C. (2016). The influence of visitor use levels on visitor spatial behavior in off-trail areas of dispersed recreation use. *Journal of Environmental Management, 170*, 79–87. http://dx.doi.org/10.1016/j.jenvman.2013.03.036

Gutzwiller, K., D'Antonio, A., & Monz, C. (2017). Wildland recreation disturbance: broad-scale spatial analysis and management. *Frontiers in Ecology and the Environment, 15*(9), 517–524. https://doi.org/10.1002/fee.1631

Hallo, J., Beeco, J., Goetcheus, C., McGee, J., Gard McGehee, N., & Norman, W. (2012). GPS as a method for assessing spatial and temporal use distributions of nature-based tourists. *Journal of Travel Research, 51*(5), 591–606. https://doi.org/10.1177/0047287511431325

Hammitt, W. E., Cole, D. N., & Monz, C. (2015). *Wildland recreation: Ecology and management* (3rd ed.). John Wiley & Sons.

Harrison, L. S. (1995). *Historic roads in the national park system.* U.S. Department of the Interior, National Park Service, Denver Service Center.

Kidd, A. M., D'Antonio, A., Monz, C., Heaslip, K., Taff, D., & Newman, P. (2018). A GPS-based classification of visitors' vehicular behavior in a protected area setting. *Journal of Park and Recreation Administration, 36*(1), 69–89. https://doi.org/10.18666/JPRA-2018-V36-I1-8287

Lawson, S., Chamberlin, R., Choi, J., Swanson, B., Kiser, B., Newman, P., Monz, C., Pettebone, D., & Gamble, L. (2011). Modeling the effects of shuttle service on transportation system performance and quality of visitor experience in Rocky Mountain National Park. *Transportation Research Record, 2244*(1), 97–106. https://doi.org/10.3141/2244-13

Lucas, R. C. (1980). Use patterns and visitor characteristics, attitudes, and preferences in nine Wilderness and other roadless areas. US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Lemons, J. (2010). Revisiting the Meaning and Purpose of the "National Park Service Organic Act." Environmental Management, 46(1), 81–90. https://doi.org/10.1007/s00267-010-9488-0

Manning, R. E. (2011). Studies in outdoor recreation: Search and research for satisfaction (3rd ed). Oregon State University Press.

Manning, R. E., Lawson, S., Newman, P., Halo, J., & Monz, C. (2014). *Principles of sustainable transportation in National Parks. Sustainable transportation in the national parks: From Acadia to Zion.* University Press of New England.

Manning, R. E. & Valliere, W. A. (2017). Coping in outdoor recreation: Causes and consequences of crowding and conflict among community residents. *Journal of Leisure Research, 33*(4), 410–426. https://doi.org/10.1080/00222216.2001.11949952

McCool, S., & Christensen, N. (1996). *Alleviating congestion in parks and recreation areas through direct management and visitor behavior. Crowding and congestion in the National Park system: Guidelines for management and research.* University of Minnesota Agriculture Experiment Station Publication 86, 67-83.

Monz, C., D'Antonio, A., Lawson, S., Barber, J., & Newman, P. (2016). The ecological implications of visitor transportation in parks and protected areas: Examples from research in US National Parks. *Transportation Geography, 51*, 27–35. https://doi.org/10.1016/j.jtrangeo.2015.11.003

National Park Service. (2013). *Foundation Document Rocky Mountain National Park.* https://www.nps.gov/romo/learn/management/upload/ROMO_Foundation_Document.pdf

National Park Service. (2020a). *National Park Service visitor use statistics IRMA Portal.* https://irma.nps.gov/STATS/.

National Park Service. (2020b). *Annual park recreation visitation (1904 – Last Calendar Year) Rocky Mountain National Park.* https://irma.nps.gov/STATS/.

Newsome, D., Dowling, R., & Moore, S. (2005). Wildlife Tourism Clevedon. Channel View Publications.

Orsi, F. (2015). *Sustainable transportation in natural and protected areas.* Routledge, Taylor & Francis Group. https://doi.org/10.4324/9781315765396

Orsi, F., & Geneletti, D. (2016). Transportation as a protected area management tool: An agent-based model to assess the effect of travel mode choices on hiker movements. *Computers, Environment and Urban Systems, 60*, 12–22. https://doi.org/10.1016/j.compenvurbsys.2016.07.008

Pettebone, D., Meldrum, B., Leslie, C., Lawson, S., Newman, P., Reigner, N., & Gibson, A. (2013). A visitor use monitoring approach on Half Dome cables to reduce crowding and inform park planning decisions in Yosemite National Park. *Landscape and Urban Planning, 118,* 1–9. https://doi.org/10.1016/j.landurbplan.2013.05.001

Pettebone, D., Newman, P., Lawson, S. R., Hunt, L., Monz, C., & Zwiefka, J. (2011). Estimating visitors' travel mode choices along the Bear Lake Road in Rocky Mountain National Park. *Journal of Transport Geography, 19*(6), 1210–1221. https://doi.org/10.1016/j.jtrangeo.2011.05.002

Riungu, G., Peterson, B., Beeco, J., & Brown, G. (2019). Understanding visitors' spatial behavior: A review of spatial applications in parks. *Tourism Geographies, 20*(5), 833–857. https://doi.org/10.1080/14616688.2018.1519720

Stanford University, & Steiner, E. (2019). Flow maps. *Geographic Information Science & Technology Body of Knowledge, 2019*(Q4).

Taczanowska, K., Muhar, A., & Brandenburg, C. (2008). Potential and limitations of GPS tracking for monitoring spatial and temporal aspects of visitor behaviour in recreational areas. In A. Raschi, S. Trampetti (Eds.), *Management for protection and sustainable development.* Proceedings of the Fourth International Conference on Monitoring and Management of Visitor Flows in Recreational and Protected Areas, Montecatini Terme, 14-19 October 2008, 451–455.

Vaske, J., (2008). *Survey research and analysis: Applications in parks, recreation, and human dimensions.* Venture.

U.S. Census Bureau. (2021). *2020 population estimates.* The United States Census Bureau. https://www.census.gov/programs-surveys/popest/technical-documentation/research/evaluation-estimates.html