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Mitigating Undesignated Trail Use: The Efficacy of Messaging and Direct Site Management Actions in an Urban-Proximate Open Space Context

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Abstract
The use and creation of undesignated recreational trails can lead to erosion, vegetation damage, unsafe trail conditions, and impacts to local wildlife. The mitigation of undesignated trail use is typically addressed indirectly through minimum-impact visitor education programs such as Leave No Trace, or directly through closures or sanctions. In this study, researchers collaborated with City of Boulder, Colorado Open Space and Mountain Parks (OSMP) staff to develop a quasi-experimental field study that examined the effectiveness of indirect (messaging) and direct (barriers) management approaches to mitigating undesignated trail use. The study applied a Theory of Planned Behavior framework, utilized Leave No Trace messaging, and employed a method to pair survey and direct observation data. A total of 2232 visitor parties were observed, and 147 surveys were collected. The combined direct (barrier) and indirect (messaging) intervention was the most effective at mitigating undesignated trail use. Implications for management and future research are discussed.

Keywords park management · leave no trace · theory of planned behavior · visitor education · recreational impact · environmental communication

Introduction

Recent trend data indicate that a continued increase in recreational use of public and protected areas nationwide, including open space, is likely to occur over the coming years (The Outdoor Foundation 2013; USDA Forest Service 2010). Research has shown that increasing visitation often leads to increased impacts to soils, vegetation, wildlife and other visitors (Hammitt et al. 2015). Public land resources in urban-proximate locations, such as the 45,000 acre Open Space and Mountain Parks (OSMP) system in the City of Boulder Colorado, may be especially susceptible to the impacts related to increased outdoor recreation visitation (Kyle and Graefe 2007). Like many public land managing agencies OSMP is charged with the often-conflicting management directives of preservation of critical plant and animal habitat, and the provision of quality opportunities for passive recreation such as hiking, horseback riding, cycling, and fishing (City of Boulder 2005). As the population across the frontrange of Colorado has steadily increased, it is now estimated that OSMP receives over 5 million recreational visits per year (Vaske et al. 2009).

Striking a balance between recreational quality and ecological integrity is a perennial concern among public land managers. The development of a recreational infrastructure of trails and recreation sites that concentrate visitor use on hardened durable surfaces is a commonly employed approach to achieving this balance (Marion et al. 2016). Of critical concern here is the notion that increased visitation often correlates to an increase in visitors traveling off of and away from sustainably developed recreational facilities,

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leading to the creation and proliferation of undesignated trails (Park et al. 2008). Accordingly, a recent inventory of OSMP land-use designation identified ~ 147 miles of designated trails across their system, and no < 170 miles of undesignated trails (VanderWoude et al. 2015). VanderWoude and colleagues (2015) suggest that if visitation increases, the extent of undesignated trail (UT) development is also likely to increase in the absence of a plan for managing the recreational desires of visitors on the OSMP system.

The OSMP Visitor Master Plan (VMP) provides “a framework for decisions that will ensure a continued high quality visitor experience, whereas at the same time ensuring that the lands are protected and preserved for future generations” (City of Boulder 2005). Importantly, the VMP mandated the development of a program to critically assess and manage undesignated trails on OSMP lands (City of Boulder 2005). To effectively reduce use of undesignated trails, OSMP must have a better understanding of which types of trail management approaches are most effective at ensuring visitor compliance (i.e., adhering to closures and staying on designated trails). An understanding of the underlying reasons (e.g., intentional or unintentional) why visitors use undesignated trails is paramount for implementing specific management actions (or combinations of actions) to reduce use of such trails. Thus, understanding the relationships between management interventions and visitor behavior is critical for realizing lasting sustainability of OSMP lands. The purpose of this study is to investigate the efficacy of a range of management actions designed to mitigate the use of undesignated trails located within the OSMP system. Working in collaboration with OSMP managers, we developed a quasi-experimental field study that applied a range of treatments in an effort to achieve the highest possible reduction in UT use.

Background and Related Literature

Undesignated trails (e.g., social, visitor-created, unofficial, or informal trails) are visible pathways created and perpetuated by visitors outside of an area’s formally managed trail system (Leung et al. 2011). These undesirable trail segments are often the product of several factors. One of these is heavy visitation coupled with diverse recreation interests, whereas another is visitors accessing points of interest off of designated trails (Guo et al. 2015). Because undesignated trails are not professionally designed, constructed, or maintained they can contribute substantially greater impacts to protected area resources than designated trails (Wimpey and Marion 2011; Marion and Wimpey 2017). The proliferation UT networks into protected landscapes and habitats threatens ecological integrity, esthetics, and visitor experiences (Leung et al. 2011). Some off-trail travel is tolerated by the ecosystem; however, the amount of soil compaction and erosion that is acceptable is weighed against the level of visitation at each site (Kuo 2002). Off-trail travel is not typically an illegal or sanctioned act on most public lands. However, when experienced at high levels it represents a visitor behavior that conflicts with resource protection objectives, prompting the need for management interventions to mitigate the problem behavior.

Problem recreation behaviors and visitor use issues are typically addressed through one of two approaches: indirectly through visitor education such as Leave No Trace or directly through enforcement, closures, or sanctions (Manning 2003; Marion and Reid 2007). Indirect management strategies have traditionally been the preferred approach to mitigating recreation-related resource impacts (Hammitt et al. 2015), as they tend to be less financially constraining, are perceived by visitors as less obtrusive, and are more in line with the experiential values associated with outdoor recreation (Marion et al. 2016; Park et al. 2008; Reigner and Lawson 2009).

Leave No Trace is the most prevalent minimum-impact educational program in use in parks and protected areas in the United States (Marion 2014). The overarching intent of the program is to educate outdoor enthusiasts about the nature of their recreation-related impact as well as teach them techniques for minimizing impact (Harmon 1997; Leave No Trace Center for Outdoor Ethics 2016; Marion and Reid 2007). The initial focus of Leave No Trace was on impacts in wilderness areas but has expanded to include other types of parks and protected areas. (Marion 2014; Marion and Reid 2001). At present, Leave No Trace has a primary focus on frontcountry area visitors, and has created numerous educational resources addressing recreational pursuits common to these areas including day hiking, dog walking, biking, running, exercise, etc. (Leave No Trace Center for Outdoor Ethics 2015; Marion 2014). In 1998, OSMP was the first urban municipality to implement a frontcountry Leave No Trace program (Reid 2000). As such, Leave No Trace education and information programs have historical precedent as an indirect management approach utilized on OSMP lands.

The extent to which indirect management strategies, such as Leave No Trace, are effective in achieving management objectives varies depending on a number of factors, such as: target resource impacts, recreation settings and contexts, characteristics and circumstances of the message, and visitor experiences and behaviors to which they are applied (Reigner and Lawson 2009). In the case of recreational trail use, much of the research has focused largely on the use of persuasive messaging techniques (see Cialdini 2003; Winter et al. 2000) to direct visitors onto designated trails and away from undesignated, or informal, trail networks (Bradford and McIntyre 2007; Kidd et al. 2015; Park et al. 2008). Injunctive prescriptive messages (i.e., positively worded messages informing visitors of behaviors that align with management objectives) with an appeal to ecological concerns are suggested as the most effective approaches when enforceable laws or regulations do not exist (Bradford and McIntyre 2007; Johnson and Swearingen 1992; Winter et al. 2000; Winter et al. 1998). With the exception of Habitat Conservation Areas, off-trail travel is not an illegal activity on OSMP lands, therefore education and information, which utilizes a prescriptive and ecologically-grounded plea might be most effective in this setting. Moreover, Manfredo and Bright (1991) found that messages are most influential when originating from a trusted source. Others have suggested messages be clear and concise, and delivered early in a visitor's planning process (Cole et al. 1997; Doucette and Cole 1993; Ham and Krumpe 1996). Messages that stimulate personal responsibility and relevance (Knapp and Forist 2014) are linked specifically to the target behavior (Widner and Roggenbuck 2000), and are contextually specific (Vagias and Powell 2010) have also proven efficacious.

In addition, the location of messages has been identified as an important factor in their influence over visitor behavior. Strategies that target visitor behavior at or near the location where a given behavior is desired have been more successful than those placed at a general location (Hockett and Hall 2007; McCool and Cole 2000; Widner and Roggenbuck 2000). For example, Bradford and McIntyre (2007) found that signs placed directly at UT intersections were significantly more effective at reducing UT use than were signs placed at an information kiosk at the area entry-point.

Finally, visitor education and information efforts are seen as having varying levels of effectiveness according to the nature of the behavior in question (Roggenbuck 1992; Vander Stoep and Roggenbuck 1996). Problem recreation behaviors can be classified into five basic types along a continuum: illegal, careless, unskilled, uninformed, and unavoidable actions (Manning 2003). Each category is influenced by visitor education and information to varying levels. On the two ends of the continuum, illegal and unavoidable actions are considered to be little influenced, whereas careless, unskilled, and uninformed actions are considered to be more amenable to education and information (Park et al. 2008). Regarding UT use, it is important to understand, for example, whether recreationists travel off designated trails knowingly with intent, or if they end up off trail accidentally due to inadequate signage or some other reason. By understanding where off-trail behaviors lay on this continuum, managers are better informed to craft strategies for addressing the underlying causes.

However, as the continuum of behavior described above suggests, a routinely applied indirect management strategy may not always be the most effective approach (McAvoy and Dustin 1983; Cole 1995), particularly in areas that receive moderate to high use (Marion et al. 2016). Direct approaches can efficiently alter visitor behavior, but need to be weighed against public perceptions, as these strategies tend to be perceived negatively and opposed by visitors (McCool and Christensen 1996). McAvoy and Dustin (1983) write that direct approaches should be implemented in conjunction with indirect measures to best influence the formation of appropriate attitudes to govern subsequent behavior. This highlights the need to consider the efficacy of a range of management interventions—from indirect to direct–in developing strategies to alter visitor behavior.

Theoretical Framework–Theory of Planned Behavior

The Theory of Planned Behavior (TPB) was used in this research as a theoretical frame by which to examine underlying cognitive factors and attitude structures that contribute to trail use behavior. Since its introduction to the literature, the TPB is recognized as one of the most frequently cited and influential models for the prediction of human behavior (Ajzen 2011). It has been celebrated for its parsimonious nature and its relative ease of implementation, and in many cases has quite good predictive ability across a variety of contexts and behaviors (Ajzen 2011; McEachan et al. 2011; Armitage and Christian 2003; Armitage and Conner 2001; Sutton 1998). At its root is the notion that behavioral intentions—sometimes also considered as motivations (Ajzen 1991)—are the most proximate predictor of one's actual behavior. It is assumed that intentions capture the motivational factors that influence a behavior—they are essentially indications of how hard people are willing to try, and how much of an effort they are willing to exert, in order to perform the behavior. As a general rule, the stronger the intention to engage in a behavior, the more likely should be its performance (Madden et al. 1992). The strength of one's behavioral intent, then, is posited to be a product of three unique antecedent constructs (Fig. 1): Attitudes toward the behavior, subjective norm assessments, and perceived

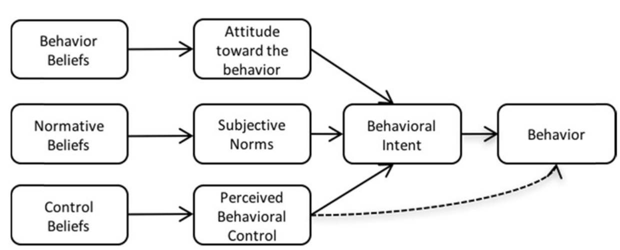


Fig. 1 Hypothesized TPB relationships (Ajzen 1991)

behavioral control (PBC). The strength of each construct is determined by an individual's underlying belief structures.

The TPB can be used to articulate persuasive messages aimed at changing behavioral intent by targeting an individual's beliefs and attitudes (Ham and Krumpe 1996). Thus, following the logic of the theory, by gaining an understanding of the extent to which the TPB constructs influence one's behavioral intentions, managers of public, and protected areas will be better equipped to develop educational strategies that work to influence positive change in visitor behavior (Vagias et al. 2014). Drawing on the work of previous researchers who have utilized the TPB in the context of minimum-impact outdoor recreation behavior (Lawhon et al. 2013; Reigner and Lawson 2009; Vagias et al. 2014), the present study utilized an extended version of the TPB to help identify those variables that exert influence over one's behavior in the context of recreational trail use.

Study Purpose

Visitor education and information campaigns have often proven to be successful means for achieving management objectives. The extant literature provides a valuable contribution to our understanding of the efficacy of these efforts, though a number of knowledge gaps still exist. For example, the predominance of research has been conducted in wilderness or backcountry settings, thus less is known of the efficacy in urban-proximate frontcountry settings. Moreover, little research has measured the effectiveness of a range of management approaches—from indirect to direct—in influencing visitor behavior. In addition, the majority of previous research has examined minimum-impact messaging generally, as opposed to Leave No Trace specifically. Finally, when researchers have been able to collect observational and survey data they have often lacked the ability to pair the data sources—a commonly mentioned suggestion for future research focused on visitor behavior in parks and protected areas. This study was designed to fill some of these gaps.

Thus, the objectives of this study were to (1) apply a range of direct and indirect site management interventions, and use unobtrusive visitor observation and survey methods to assess the effectiveness of each of the interventions in mitigating UT use on OSMP lands; and (2) to pair observed OSMP trail users' response to treatments/control with survey data from those same observed individuals or parties for comparative analysis of observed behavior and reported behavior. This article reports on the results of this study, focusing on the following research questions:

1. Which management strategy (intervention) is most effective in mitigating UT use?
2. To what extent do the TPB constructs work to explain behavioral intentions to travel only on designated trails?
3. To what extent do the TPB constructs work to explain actual trail use behavior?

Methods

Research Design

This study involved a quasi-experimental design in which we devised a field experiment to determine the effectiveness of a range of educational and site management actions aimed at mitigating the use of undesignated trails on OSMP lands. Data were collected through both direct visitor observation and visitor surveys. Data collection methods allowed for the pairing of observation and survey data, which facilitated a more robust understanding of the efficacy of the various educational messages and site management strategies. The study was approved by the first author's institutional ethics review board, and all participants provided informed consent during participation.

Site Selection

A total of 20 UT intersections were selected for inclusion in the study. The sites were selected by OSMP managers using a systematic randomized sampling process designed to provide a representative sample of system-wide trail characteristics. Using GIS software and *spsurvey* in the statistical software R, the initial population of 1542 points (trail intersections) was pared down to 870 after excluding those located at intersections that included: (1) roads; (2) facility access paths; (3) driveways; (4) cattle trails not used as visitor trails; and (5) climbing access. An oversample of 40 sites was drawn from the population of 870. Next, during field evaluations, 13 of the initial sites were rejected for logistical reasons and replaced with the next 13 oversamples that met the study site criteria. The final sample of 20 sites included 16 "high" volume sites and 4 "low" volume sites, which was determined to be representative of the system based on the approximate distribution of these categories in the sample frame.

Management Actions Examined in the Study

In addition to a control condition, which represented no management action, the four treatments under study included two different signs containing informational messages (i.e., indirect management strategies), a wooden barrier (i.e., direct management strategy), and a wooden barrier combined with an informational message (i.e., paired direct and indirect management strategy). The signs containing informational messages were developed based on recommendations of previous research reviewed above, and were designed and printed by the OSMP contracted sign manufacturer. As such, they were of the same size and color as other official OSMP signage, included OSMP and Leave No Trace logos (i.e., originated from official and trusted sources), and contained clear and concise language. The wooden barriers were also of the same design used across the OSMP system.

The management conditions under examination consisted of the following:

- Control condition: no sign or barrier treatments in place;
- Treatment 1: trailside sign with message #1—"Stay on designated trails: even when wet and muddy, to protect trailside plants and minimize erosion. This is not a designated trail" (Fig. 2);
- Treatment 2: trailside sign with message #2. "To protect OSMP lands: please stay on designated trails. This is not a designated trail" (Fig. 3);
- Treatment 3: physical barrier (buck and rail style fencing) constructed of logs commonly used in the OSMP system (Fig. 4);
- Treatment 4: same physical barrier used in Treatment 3 combined with sign from Treatment 2 affixed to the center (Fig. 5).

Each of the five conditions was tested at 20 randomly selected locations (UT junctions) in June 2015. Stratified sampling took place in June and July of 2015. Control days, in which no treatments were in place, were also included in the sampling stratification scheme. Sampling was divided to ensure a representative sample of visitors across treatment type (and control), location, day of the week, and sampling period. Sampling periods consisted of 3-hour blocks, dividing the day as follows: early morning (6:30 a.m.–9:30 a.m.); late morning (10:00 a.m.–1:00 p.m.); early afternoon (1:00 p.m.–4:00 p.m.); and late afternoon (4:30 p.m.–7:30 p.m.).

Fig. 2 Treatment 1: education message 1

Fig. 3 Treatment 2: Education Message 2

Fig. 4 Treatment 3: Barrier

Fig. 5 Treatment 4: Barrier & Ed Message 1

Development of Educational Messages

A visitor elicitation study was conducted to inform our decision as to which messages might be most influential in this particular location and context. Applying elicitation study methods used in other park-based communications research (Curtis et al. 2010; Downs and Hausenblas 2005; Sutton et al. 2003), in October 2014, the authors approached OSMP visitors and asked them to complete a one-page survey about the potential messages. The survey included nine messages that were crafted based upon recommendations reported in the persuasive communications literature (see Cialdini et al. 2006; Hockett and Hall 2007; Widner and Roggenbuck 2000; Winter 2006). Ultimately, respondents evaluated two components of each message: (1) the persuasiveness of the message; and (2) the likelihood that the message would influence the visitor to stay on designated OSMP trails. The two statements that were indicated as being the most influential were selected for use in the study: (1) "Stay on designated trails: Even when wet and muddy, to protect trailside plants and minimize erosion. This is Not a Designated Trail" (Treatment 2); and (2) "To Protect OSMP Lands: Please Stay on Designated Trails. This is Not a Designated Trail" (Treatment 3). Message 1 was the highest rated of the two and was therefore also selected as the message to be used in Treatment 4.

Treatments 1 and 2 (trailside signs) were affixed to portable bases called "little buddies"—a 4 × 4 post connected to a metal stand (see Fig. 6). These were transported to the study location by the researchers and put in place at the start of a sampling shift. They were then removed at the end of the shift. Treatments 3 and 4 (barriers) were installed by OSMP staff prior to the start of a sampling period and removed immediately following. No treatments were left in place for > 24 h in an effort to minimize any habituation or bias that might be associated with extended exposure to a specific treatment.

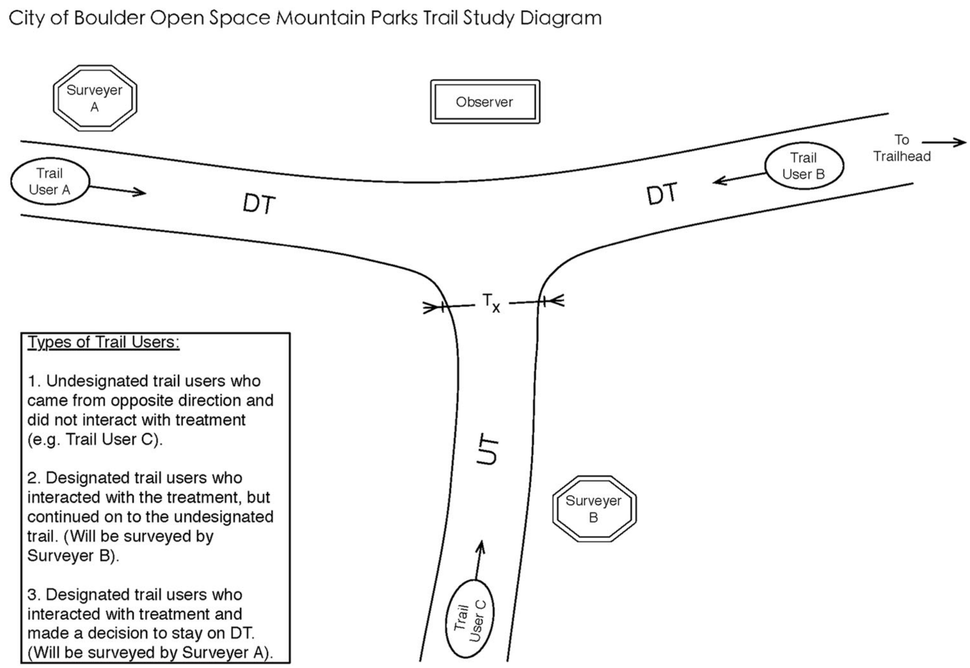
Fig. 6 Portable trailside sign ("little buddy") used in the field

Survey Administration

On-site visitor intercept surveys were administered in tandem with observations on 15 randomly selected sampling days. During these "paired" sampling days, field researchers worked in teams of three, which consisted of an observer and two survey administrators—one on the designated trail (DT) and another on the UT (see Fig. 7). Survey administrators were positioned in a location out of sight of the trail junction, and typically 50–100 yards away. Distancing survey administrators from the trail junction not only served to keep them out of sight but also created a time and distance gap between intervention and researcher contact so that visitors were less likely to associate the survey with the experimental site management aspects of the study. In other words, we did not want visitors to perceive that their being approached for a survey was associated with the treatment in place or because of their behavior or actions at the trail intersection. Two-way radios were used to communicate visitor party pairing identifiers and pairing identification numbers between observers and survey administrators. Thus, every visitor party who was recruited to participate in the survey had an associated set of observed behavior characteristics/attributes.

- Every visitor party who was traveling on the UT was approached by Surveyer B.
- On treatment days (days when one of the four interventions were in place) every DT user who passed by the trail junction and interacted with the study intervention was approached by Surveyer A. An interaction was defined as obvious and meaningful engagement (operationalized as three seconds or more of attention) with the intervention. DT users who had no interaction with an intervention were not approached. With the primary focus of this research being the influence of management interventions on behavior we made the decision to only survey DT trail users who had an interaction with the intervention.
- On control days (days when no intervention was in place), the sampling frame included every third visitor party who passed the trail junction traveling on the DT. Because there was no treatment in place, the sampling parameters defined for treatment days (i.e., an interaction with study intervention) did not apply. Thus, we decided to approach every third visitor party as a systematic randomization strategy. If this individual/party refused, the survey administrator approached every subsequent party until a survey was accepted. Once a survey was administered, they reverted back to every third DT user.

Fig. 7 Field research diagram visitors were recruited to participate in the survey according to the following parameters:



Behavioral Observation Methods

Unobtrusive visitor observation was used to collect behavioral data at the 20 research sites. Observers positioned themselves in a location out of sight (as possible) of the trail intersection so as to not influence visitor behavior. On "observation only" days, a single observer recorded observations for every individual or visitor party that passed the sample point capturing the specifics of their behavior as it pertains to study objectives (i.e., whether the visitor was traveling on the DT or UT). A visitor party was considered as any recreation group that, in the best judgment of the observer, was intentionally traveling together. During "paired" sampling days (when surveys were also being administered), the field crew included two survey administrators, in which case the observers also noted visitor characteristics such as the color of lead person's bottoms and shoes to ensure that observation ID numbers could be accurately paired with survey ID numbers. No personally identifiable markers were captured by observers.

Survey Instrument

The survey instrument was developed through a collaborative, iterative review process between the research team, and OSMP staff. The instrument was framed within the context of the of the Theory of Planned Behavior (Ajzen 1991) and developed to incorporate established natural resource-based human dimensions questions, including established Leave No Trace-focused questions that have been used in numerous peer-reviewed studies (Lawhon et al. 2013; Taff et al. 2014; Vagias et al. 2014), questions regarding trail behaviors and perceptions of intervention treatments (Park et al. 2008), and questions about visitor use preference, history, and basic demographic information. In the early development of the survey instrument, it was pretested with 30 undergraduate students; and was subsequently field-tested with visitors on OSMP properties in May 2015. Pretesting allowed respondents to inform researchers of potentially confusing wording and layout issues.

Variable Measurement

The primary independent variables of interest in the survey were framed within the context of the TPB framework (Ajzen 1991). The specific items and question wording were adapted from previous Leave No Trace research (Lawhon et al. 2013; Taff et al. 2014; Vagias and Powell 2010), and reworded minimally to reflect behaviors specific to recreational trail travel. TPB constructs examined in the survey included: attitudes toward Leave No Trace trail use practices (how appropriate or inappropriate practices are perceived), perceived effectiveness of Leave No Trace practices, PBC (perceived difficulty) of Leave No Trace practices, and subjective norms. The dependent variables were behavioral intent, measured through self-report in the survey, and actual behavior, which was measured through direct observation. The following sections discuss the measurement strategy for each construct.

Table 1 Descriptive statistics and reliability analysis for TPB items and latent constructs

Construct and items	Scale mean/item mean		α if item deleted	α
Attitude toward behavior[a]	Scale $M = 4.73$		–	.948
	Mean	SD		
Traveling off a designated trail to experience the natural environment	4.97	1.711	.877	
Traveling around muddy spots on a designated trail	4.43	1.633	.917	
Traveling off a designated trail to explore	4.87	1.741	.868	
Traveling off a designated trail to take photos	4.81	1.661	.876	
Traveling off a designated trail to get away from crowds on the trail	5.13	1.600	.879	
Traveling off a designated trail because there is an alternative established path	4.17	1.917	.911	

[a]Items measured using a seven-point scale (1 = very appropriate to 7 = very inappropriate)

Table 2 Descriptive statistics and reliability analysis for perceived effectiveness construct

Construct and items	*Scale mean/ item mean*		α if item deleted	α
Perceived effectiveness[a]	Scale $M = 5.28$		–	0.661
	Mean	SD		
Staying on a designated trail	5.55	1.352	0.516	
Traveling in the middle of a designated trail, even when wet or muddy	4.98	1.506	0.569	
Traveling on a designated trail, even when passing other visitors	5.24	1.403	0.483	
Staying off a designated trail when conditions are wet and muddy	4.86	1.682	0.773	

[a]Items measured using a seven-point scale (1=Never effective to 7=Effective Every Time)

Attitudes

In this study, we were interested in examining attitudes toward Leave No Trace recommended trail-use behaviors. Specifically, we measured perceived appropriateness, or inappropriateness, of the behaviors. Respondents were asked to evaluate six trail-use behaviors using a seven-point Likert-type scale, anchored from 1 = Very Inappropriate to 7 = Very Appropriate (Table 1). The statements as written are considered inappropriate behaviors under strict interpretation of Leave No Trace. The responses categories were reverse-coded during analysis to match the directionality of the other constructs used in the TPB model (i.e., Greater mean scores suggest responses more in line with Leave No Trace, whereas lower scores indicate less congruence). The six items were combined to create a summated rating scale (Vaske 2008). The items had an internal consistency of $a = .95$.

Perceived Effectiveness

The effectiveness construct examined respondent perceptions regarding the extent to which practicing Leave No Trace trail-use behaviors work to reduce negative environmental impacts on OSMP lands. Although the notion of perceived effectiveness is not included in the TPB model as originally conceptualized, Ajzen (1991) writes that the possibility of adding additional predictor variables to the model was explicitly left open. The addition of perceived effectiveness measures has proven to be an important explanatory variable in previous research (see Lam 2006; Lawhon et al. 2013).

Perceived effectiveness was assessed through four behavior statements asking respondents to indicate the extent to which each behavior reduces negative impacts (e.g., Traveling in the middle of a DT, even when wet or muddy), whereas visiting OSMP (Table 2). These items were rated on a seven-point Likert-type scale anchored from 1 = Never Effective to 7 = Effective Every Time. These four items were combined to create an effectiveness index. Cronbach's alpha for this index was adequate ($a = .66$).

PBC (Perceived Difficulty)

PBC refers to an individual's perceived control over performing a specific behavior (Ajzen 2002). PBC is

Table 3 Descriptive statistics and reliability analysis for PBC construct

Construct and Items	*Scale mean/ item mean*		α if item deleted	α
Perceived behavioral control—Perceived difficulty[a]	Scale M = 5.44		–	.888
	Mean	SD		
Staying on a designated trail	5.71	1.500	0.876	
Traveling in the middle of a designated trail, even when wet or muddy	4.99	1.608	0.890	
Traveling on a designated trail, even when passing other visitors	5.46	1.505	0.868	
Traveling on a designated trail, even when you have previously traveled on an undesignated trail in the area	5.38	1.450	0.856	
Traveling on a designated trail, even when an undesignated trail is available in the area	5.57	1.304	0.854	
Traveling on a designated trail, even when you have observed another visitor traveling on an undesignated trail	5.54	1.480	0.867	

[a]Items measured using a seven-point scale (1=Very Difficult to 7=Very Easy)

Table 4 Descriptive statistics and reliability analysis for subjective norms construct

Construct and items	*Scale mean/ item mean*		α if item deleted	α
Subjective norms[a]	Scale M = 4.92		--	0.912
	Mean	SD		
Because visitors are encouraged to stay on designated trails	5.25	1.613	0.895	
To not damage the soils and vegetation	6.02	1.561	0.907	
To not break the rules	4.59	2.013	0.895	
Because I do not want anyone to see me travel off designated trails	3.91	2.176	0.906	
Because it is unfair for me to travel off designated trails while many other visitors do not	4.48	2.043	0.896	
Because Leave No Trace promotes traveling on designated trails	5.41	1.900	0.900	
Because I feel better about myself by not traveling off designated trails	4.76	2.173	0.894	

[a]Items measured using a seven-point scale (1 = Not at all Important to 7 = Extremely Important)

understood to be a multidimensional construct—an amalgamation of both perceived control and perceived difficulty (Trafimow et al. 2002). Perceived control refers to the extent to which a behavior is considered to be under one's complete voluntarily control, whereas perceived difficulty is the extent to which the behavior is considered to be easy or difficult to perform. Following the recommendations of previous Leave No Trace research (Lawhon et al. 2013; Vagias et al. 2014), this study draws on the latter dimension, examining respondents' perceived physical ease, or difficulty of performing various Leave No Trace trail-use behaviors. PBC was evaluated through six behavioral statements asking respondents to indicate how difficult each would be for them to do while visiting OSMP (Table 3). These items were rated on a seven-point Likert-type scale anchored from 1 = Very Difficult to 7 = Very Easy. The Cronbach's alpha for the PBC index was 0.89, indicating good reliability among measures.

Subjective Norms

The influence of subjective norms was measured through seven items that asked respondents to indicate the extent of their motivation to comply with social and personal pressures. Respondents were provided a list of reasons why visitors might be influenced to use only designated trails, and asked to indicate how important each of the reasons would be for them to travel only on designated trails while visiting OSMP in the future (Table 4). Items were rated on a seven-point Likert-type scale where 1 = Not at all important and 7 = Extremely Important. Normative items examined subjective evaluations of local rules and Leave No Trace recommendations, personal norms, and perceived social norms. All seven items were combined to create a subjective norms index. Cronbach's alpha for internal consistency was 0.91, indicating good reliability among measures.

Table 5 Descriptive statistics and reliability analysis for behavioral intent construct

Construct and items	*Scale mean/ item mean*		α if item deleted	α
Behavioral intent[a]	Scale M = 5.70		–	0.904
	Mean	SD		
Staying on a designated trail	5.94	1.217	0.884	
Traveling in the middle of a designated trail, even when wet or muddy	5.46	1.375	0.909	
Traveling on a designated trail, even when passing other visitors	5.78	1.251	0.888	
Traveling on a designated trail, even when you have previously traveled on an undesignated trail in the area	5.59	1.390	0.875	
Traveling on a designated trail, even when an undesignated trail is available in the area	5.66	1.207	0.879	
Traveling on a designated trail, even when you have observed another visitor traveling on an undesignated trail	5.76	1.217	0.884	

[a]Items measured using a seven-point scale (1 = Extremely Unlikely to 7 = Extremely Likely)

Behavioral Intentions

A core tenet of the TPB is that behavioral intentions are the most proximal predictor of actual behavior. It is assumed that intentions capture those motivational factors that influence a behavior (Ajzen and Driver 1992). In this study, behavioral intent was measured by asking respondents their likelihood of engaging in specific behaviors (Table 5). This block of items included the same behaviors as listed in the PBC scale, though this time the phrase preceding the scale was "How likely are you to do this in the future?" The response format was a seven-point Likert-type scale anchored from 1 = Very Unlikely to 7 = Extremely Likely. Cronbach's alpha for the behavioral intent index was 0.90, indicating good internal consistency.

Data Analysis

All data analysis was performed using IBM Statistical Package for the Social Sciences (SPSS) software, version 22. Survey and observation data were initially entered into an Excel spreadsheet and then imported into an SPSS database for analysis. Univariate and bivariate descriptive statistics were conducted first to identify outliers and missing data. Surveys that were < 75% complete were deleted from the data set. Only matched data were used in the analysis. That is, cases that included both survey and observation data. Next, the survey and observation data were analyzed as discussed below to examine several research questions.

First, we utilized chi-square analysis to examine the difference in treatment effectiveness (RQ1). Further post hoc analyses using Fisher's exact tests with continuity correction and phi coefficients for effect size were utilized to examine statistical significance of each treatment compared with control conditions. Next, we examined the extent to which an extended version of the TPB would account for intentions to travel only on the designated trails (RQ2). As such, all independent variables described previously were entered into a multiple correlation regression path model to explore which variables serve as predictors of behavioral intent. In answering RQ3, we tested the influence of the same independent variables as in the previous on actual behavior, which was measured as a dichotomous (yes or no) dependent variable. Thus, owing to the dichotomous nature of the dependent variable, logistic regression procedures were utilized in this analysis. Logistic regression is a recommended statistical technique for predicting the probability that an event will or will not occur and identifying the variables useful in making the prediction (Vaske 2008). Results of a logistic regression will provide insight as to how well the constructs operationalized in the TPB model predict actual behavior.

Results

Sample Characteristics

A total of 147 respondents completed a survey, for a total response rate of 68%. Upon removal of incomplete surveys and cases that lacked necessary pairing indicators, a total of 101 cases were included in the analyses reported here. Of these, 44 (44%) were observed using undesignated trails, and the other 57 (56%) were designated trail users. A total of 2232 visitor parties were observed during the study, the majority of those were walking/hiking (68%) and traveling alone (58%).

RQ1: Which management strategy (interventions) is most effective in mitigating the use of undesignated trails?

Table 6 Treatment effectiveness

	Control	Treatment 1: Ed Message 1	Treatment 2: Ed Message 2	Treatment 3: Barrier	Treatment 4: Barrier and Ed Message 1
Observed					
Sample size	349	337	261	240	220
Designated trail use rates	91.4%[a]	90.8% [a]	93.9% [a]	94.2% [a]	96.8% [b]

[a, b]Rates with different superscripts are significantly different compared to control conditions (p < .05)

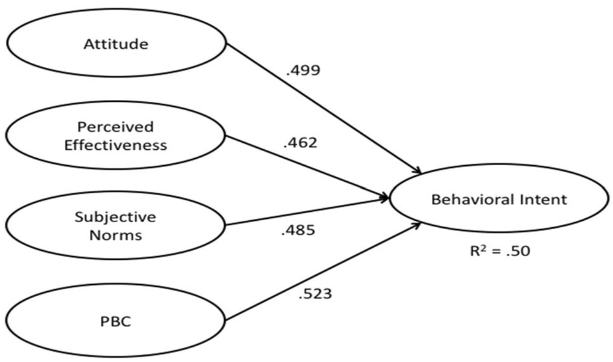


Fig. 8 TPB Model 1: Multiple regression predicting behavioral intent

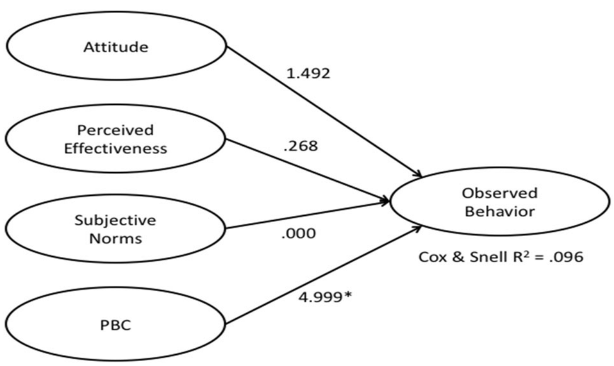


Fig. 9 TPB Model 2: Logistic regression predicting actual behavior

Observation data indicate that Treatment 4 (combined physical barrier and educational message) was the most effective at mitigating UT use (Table 6). This method was ~ 97% effective at directing visitors to proceed onto the DT rather than traveling on the UT. This treatment was followed in effectiveness by the physical barrier (Treatment 3), which was 94% effective, and Treatment 2, which was also 94% effective. Further post hoc analysis revealed that only Treatment 4 produced a statistically significant reduction in UT use compared with control conditions ($x^2 = 6.506$, $p < .05$).

RQ2: What is the influence of attitude, perceived effectiveness, subjective norms, and PBC on self-reported behavioral intent?

Results of the multiple regression path analysis indicated that attitudes, perceived effectiveness, PBC, and subjective norms have a significant and positive linear relationship with behavioral intent (Fig. 8). That is, those who hold favorable attitudes towards Leave No Trace behaviors, positive perceptions of the effectiveness of such behaviors, perceive the behaviors as easy to perform, and are positively motivated by subjective norms, were more likely to report intentions to use designated trails. These variables account for approximately 50% of the variance in behavioral intent (F (4, 73) = 17.007, p < .001). PBC held the strongest influence over behavioral intentions (β = .325), followed by subjective norms (β = .245).

RQ3: What is the influence of attitude, perceived effectiveness, subjective norms, and PBC on actual (observed) behavior?

To answer the third research question, we examined the same independent (predictor) variables as in Model 1 above in a logistic regression model (Fig. 9). In this analysis, behavior was used as the dependent (outcome) variable, which was coded and operationalized as a binary, where 0 = respondents who made a decision to use an UT, and 1 = those who decided to travel on the DT.

Results indicate the predictor variables in the model account for approximately 10% (Cox & Snell R2 = .096) of the variance in trail use behavior. The Cox & Snell R2 provides an approximation of the proportion of the variance in the dependent variable that is accounted for by the independent variable - a logistic analogy to the R^2 (coefficient of determination) in a linear regression (Vaske 2008). The relatively small Cox & Snell coefficient suggests that behavior in this analysis is little explained by the TPB constructs operationalized in the study. Additionally, the model correctly classified 84% of DT users, but only 47% of undesignated trial users, correctly classifying 68% of cases overall. In other words, the classification of UT users would have been more accurate if researchers had simply flipped a coin. This lends further evidence that the TPB constructs were not reliable predictors of actual behavior.

Moreover, the initial model indicates that of the predictor variables in the model, only PBC is significantly related to the variance in behavior (Wald = 4.999, p < .05). Attitudes, subjective norms, and perceived effectiveness did not contribute significantly to the explanatory ability of the model and were dropped in subsequent model iterations. The final model suggests PBC to be the single best predictor of actual behavior (Wald = 7.505, $p < .01$). In other words, the extent to which behaviors are perceived to be completely within one's volitional control appears to be the most important factor influencing behavior.

Discussion

The purpose of this research was to examine the effectiveness of a range of management interventions to minimize the use of undesignated trails. One of the strengths of this study was the consistent observation methodology, which enabled the researchers to document visitor behaviors and ultimately provided highly accurate data regarding treatment efficacy. Using the Theory of Planned Behavior as a theoretical framework we identified factors most likely to predict behavioral intentions for trail use. By pairing observation data with survey data we were able to carry the analysis of those predictors one step further and determine the extent to which they hold in the prediction of actual behavior.

Observation data indicated the majority of visitors were traveling on DTs, as ~10% were observed traveling on UTs. Though this is a comparatively small percentage of overall trail use, previous research suggests that a small number of visitors can create visible and lasting impacts to ecological systems (see Marion et al. 2016), such as the proliferation of the numerous UTs (i.e., the ~ 170 miles of UTs) on the OSMP system.

We found a relationship between the management treatments utilized in this study and a decrease in the use of undesignated trails, though the level of effectiveness depended on the type of treatment in place. While the results of Treatment 1 ("Stay on designated trails: Even when wet and muddy, to protect trailside plants and minimize erosion. This is Not a Designated Trail") suggested that it was slightly less effective than control conditions; all other treatments reduced use of UTs. However, X^2 post hoc analyses comparing treatment to control conditions reveal that only Treatment 4 (combined barrier and education message) produced a statistically significant reduction in UT use from control conditions.

Although these results indicate that among the treatments utilized in the study only Treatment 4 produced a statistically significant reduction in UT use compared with control conditions, they should be interpreted with caution from an applied management perspective. That is, a statistically significant relationship may not necessarily translate to one of practical significance (Vaske 2008). In terms of practical application, it may not be physically, esthetically, or economically practical to treat every UT intersection with a combination barrier and educational sign. Therefore, Treatment 2 should not be eliminated as a plausible management option based solely upon the statistically significant test result associated with Treatment 4. In cases where UT use is high or very high Treatment 4 may be warranted. But in other contexts that see relatively low levels of UT use a more minimalist approach (i.e., Treatment 2) may be justified. Ultimately, these results suggest that a range of UT management options exist, each with different levels of effectiveness, which provide managers a set of alternative approaches for use in the mitigation of UT use depending on resources, management objective, and context.

The use of the TPB framework provided valuable insight to the cognitive factors that influence ones intended trail-use on OSMP lands. We found that attitudes (regarding the appropriateness and effectiveness of behaviors), subjective norms, PBC, were all determinants of behavioral intentions. PBC (perceived difficulty) and subjective norms were the strongest individual predictors. Overall this model explained ~ 50% of the variance in intentions to travel on designated trails.

These findings are comparable to the findings of other studies using the TPB to understand minimum-impact Leave No Trace behaviors. For example, Vagias and others (2014) found PBC to be the primary predictor of behavioral intent for Leave No Trace practices in Olympic National Park. Although at Glacier National Park he found that PBC and subjective norms worked to influence intentions. Lawhon and colleagues (2013) found perceived effectiveness to be the strongest predictor of intentions for Leave No Trace behavior in Rocky Mountain National Park. Finally, Reigner and Lawson (2009) applied the TPB to examine off-trail behavior in the context of exploring the pools of 'Ohe'o in Haleakalā National Park. They found that normative beliefs hold the strongest influence over intentions to explore the pools. Taken together, the results of these studies seem to suggest that the formation of behavioral intentions in an outdoor recreation context varies, among other things, by location, the specific behavior in question, and site-specific features such as minimum-impact information and educational messaging. In other words, there is no perfect formula for predicting intentions across all situations; therefore, it behooves managers to support site-specific research as one approach to developing strategies for mitigating problem recreation behaviors.

Although understanding behavioral intentions does well to inform the development of management interventions, intentions do not always directly correlate to subsequent behaviors. The observation methods developed in this study allowed us to examine the contrasts between self-reported intentions and actual behavior. In comparing the results of the linear and logistic regression models in terms of the predictive ability of the independent variables, we found the prediction of actual behavior to be less accurate than the prediction of behavior intentions. These results suggest that there is a fairly substantial disconnect between what visitors said they would do and what they actually did.

This result could be interpreted in several ways. One possible explanation is related to social desirability in self-report data. In other words, in the presence of a researcher respondents might have provided responses to the survey based on what they thought was the appropriate response regarding trail behavior. However, their trail use decision was not influenced by researcher presence, as they were not aware of the field observations being conducted.

Another possible explanation is that respondents did in fact have strong intentions to travel only on designated trails as suggested by their survey responses, but the introduction of other intervening factors, perhaps beyond their control, had stronger influence over their eventual behavior. As suggested by both regression models, PBC (operationalized as perceived difficulty) was the most salient factor influencing one's trail use behavior. That is, in cases when the use of a DT was perceived as difficult or under less control of the visitor, the likelihood of DT use was significantly lower. For example, if a visitor was unaware of the difference between a UT and a DT, perhaps owing to inadequate trail demarcation, the decision about which trail to use was likely perceived as a difficult decision. Further cross-examination of survey and observation data provided some clarity to this notion.

More than 40% of survey respondents indicated they were unaware of UTs in the OSMP trail system. This aligned with paired survey and observation data, as ~ 50% of visitors who were observed and surveyed while traveling on a UT reported that they 'always' use DTs, suggesting that these visitors did not know they were in fact traveling on a UT. Furthermore, UT respondents were significantly more likely to report not knowing if they traveled off a DT. Observed behavior paired with survey responses showed that almost half of UT users reported they had not traveled off trail, and ~ 20% of UT users were unsure if they had traveled off the DT. Although being unaware may account for a substantial amount of the UT use on OSMP lands, a considerably smaller number of UT users indicated that they had seen management signs than DT users. Thus, this suggests a small segment of individuals—as also noted through observation data—will use UTs despite management interventions.

Open-ended comments on the survey provide additional insight into the difficulty of traveling exclusively on designated trails, as multiple respondents suggested there is a need to better clarify which existing OSMP trails are UTs and DTs. For example, one respondent wrote, "Often it is difficult to tell where exactly designated trails exist because of so many social trails." Another stated, "When trails have extreme braiding or social trails it is hard to know designated trails." A third respondent added, "I don't know if I should stay on trail when wet/muddy, and if walking in the middle of trail is best - signage would be good if that's what is right."

Taken together, these results point to the need for management actions designed to make it easier for visitors to differentiate between UTs and DTs. We recommend the use of consistent dissemination of information, signage, and management interventions throughout the trail system that signify which trails are DTs. For example, existing infrastructure on UTs, such as block steps, water bars, or small signs indicating no mountain biking may confuse visitors, as those are typically visual cues that indicate a managed (designated) trail segment. Thus, eliminating existing infrastructure on current UTs, coupled with the implementation of Treatment 4 (i.e., educational message and barrier) from this study could enhance mitigation efforts. Given the high visitor use of OSMP, it is important to consider wide-scale implementation of those management actions that are most effective in order to improve compliance by the majority of visitors, and in particular those existing UT users.

An additional finding worth note is that, according to survey results, visitors to OSMP largely believe that recreation behaviors have the potential to cause both ecological and social impact, and the majority of respondents indicated they would change their behaviors if they learned their actions were damaging the environment. Of the list of potential activities provided for reducing negative impacts in OSMP, Adhering to messages on posted signage was reported to be the most effective, followed by Staying on a DT. Furthermore, Adhering to messages on posted signage was reported to be the easiest of the behaviors to perform. Aligning with the message in treatments 1 and 4 ("Stay on designated trails: Even when wet and muddy, to protect trailside plants and minimize erosion. This is Not a Designated Trail"), the majority of respondents indicated that the most important reason for only using DTs was To not damage soils and vegetation. Based on these findings, it is recommended to consider the use of attributional-based messages in the design of future information and education campaigns. Although attribution theory was not directly applied or tested in this study, previous research suggests attributional messaging to be a particularly effective approach to visitor messaging.

Attribution theory posits that people often interpret their behavior in terms of its cause, and these attributions have a central role in human behavior (Kelley and Michela 1980). Previous studies (Alessa et al. 2003; Bradford and McIntyre 2007) have found that personal attribution is inversely related to depreciative behaviors. That is, the more visitors believed their behavior had the potential to cause resource degradation, the less likely they were to engage in depreciative behavior. Interestingly, Bradford and Mcintyre (2007) found that recreationists typically do not view themselves as the cause of impacts—they tend to attribute impacts to the behaviors of others. Thus, the use of messages informing visitors their personal recreation behaviors cause, or have the potential to cause, social and ecological resource degradation on OSMP lands is warranted.

Limitations and Future Research

With regard to methodological considerations and future research, this study demonstrated the strength in pairing self-reported survey data with actual behavioral observations. As noted, self-reported behaviors do not always align with the actions visitors take in the environment. Thus, when feasible, future studies should consider pairing visitor surveys and observations. Although it is important to consider systematic approaches to understanding visitor use, further examination of the most effective treatment in this study, set-up long-term in high UT use locations could yield greater understanding of the influence of paired indirect and direct management actions on UT use. For example, if the entire DT trail system and associated UT junctions within a predetermined area were treated with the barrier and educational signage over a period of 2 years for instance, researchers, and managers could monitor visitor attitudes and behavior change with the methods used in this study. Furthermore, expanding the study over a multi-year period could afford the opportunity to measure ecological change (e.g., vegetation regrowth), resulting from treatment application.

Observers used their best judgment when determining whether a particular trail user had an interaction with a treatment or control. Although it was generally easy to detect “no treatment interaction” and “stop and read,” it was more challenging to determine whether a trail user should have been categorized as “pass and read.” Consistent treatment placement (i.e., 5–10 feet from the point of entry onto an UT) was established to minimize error, and accurately determine visitor intention.

Every effort was made to provide a robust, evenly distributed stratified sample, given the vast number of strata, the limited time span of this study, and the available resources. However, there are limitations that should be noted. For example, this sampling effort took place over 25 days, during a 30-day (1-month) period. Visitation patterns and behaviors may have been subject to weather or other environmental factors beyond our control. In addition, each of the 20 sites received all five of the treatments, however, a.m./p.m. and weekday/weekend stratification was not evenly distributed, given the 1-month sampling period. Finally, this study only incorporated 20 randomly selected sites, and other OSMP UT sites may have produced alternative visitor behaviors and associated perceptions.

Although this study attempted to represent system-wide use, some of the sampling sites selected for this study receive relatively low visitation, which is not ideal for a visitor survey. Thus, this is a trade-off. For instance, although the total *N* could have been increased if the research had taken place at consistently busier OSMP locations, the results would not have represented the entire system, as this study attempted to do. In addition, owing to some of the selected sampling sites, the survey sample size is small compared to the large number of visitors observed as part of this study. This can partially be attributed to the purposeful sampling approach whereas only individuals that interacted with a treatment were asked to complete a survey. Finally, it should be noted that some visitors may have felt and acted upon social desirability (i.e., provide responses that they think coincide with the survey administrator’s viewpoints) (Vaske 2008); however, staff were trained extensively to minimize any bias.

Conclusion

Through a rigorous quasi-experimental design, this study examined the effectiveness of indirect and direct management approaches for reducing the use of undesignated trails on OSMP lands. The management actions applied in this research, particularly, the educational message paired with a physical barrier, can effectively influence behavior and significantly reduce UT usage from baseline control conditions. Furthermore, the data provide empirical evidence regarding a range of UT management options, each with different levels of effectiveness, which provides managers a set of alternative approaches for mitigating the use of UTs on the OSMP system. OSMP staff can utilize the data provided by this research, combined with known practical constraints (i.e., human or financial resources, site characteristics, esthetics, etc.) to make informed decisions about the most appropriate approach to mitigating the use of undesignated trails on OSMP lands.

Although limited research of this kind has been done in national parks and wilderness settings, most of which has been hypothetical and attitudinal rather than behavioral and experimental (Johnson and Swearingen 1992; see Park et al. 2008), we are aware of no such studies of this kind that have been conducted on open space lands to date. As such, this multi-method, quasi-experimental study is a unique addition to the scientific and professional literature on parks and protected areas, and adds to the minimal body of literature on alternative management practices for reducing visitor impacts in parks and protected areas. Studies such as this, in an open space context, may be particularly useful for both informing educational efforts and management actions that can be implemented by managers as they work to reduce recreation-related impacts.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

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